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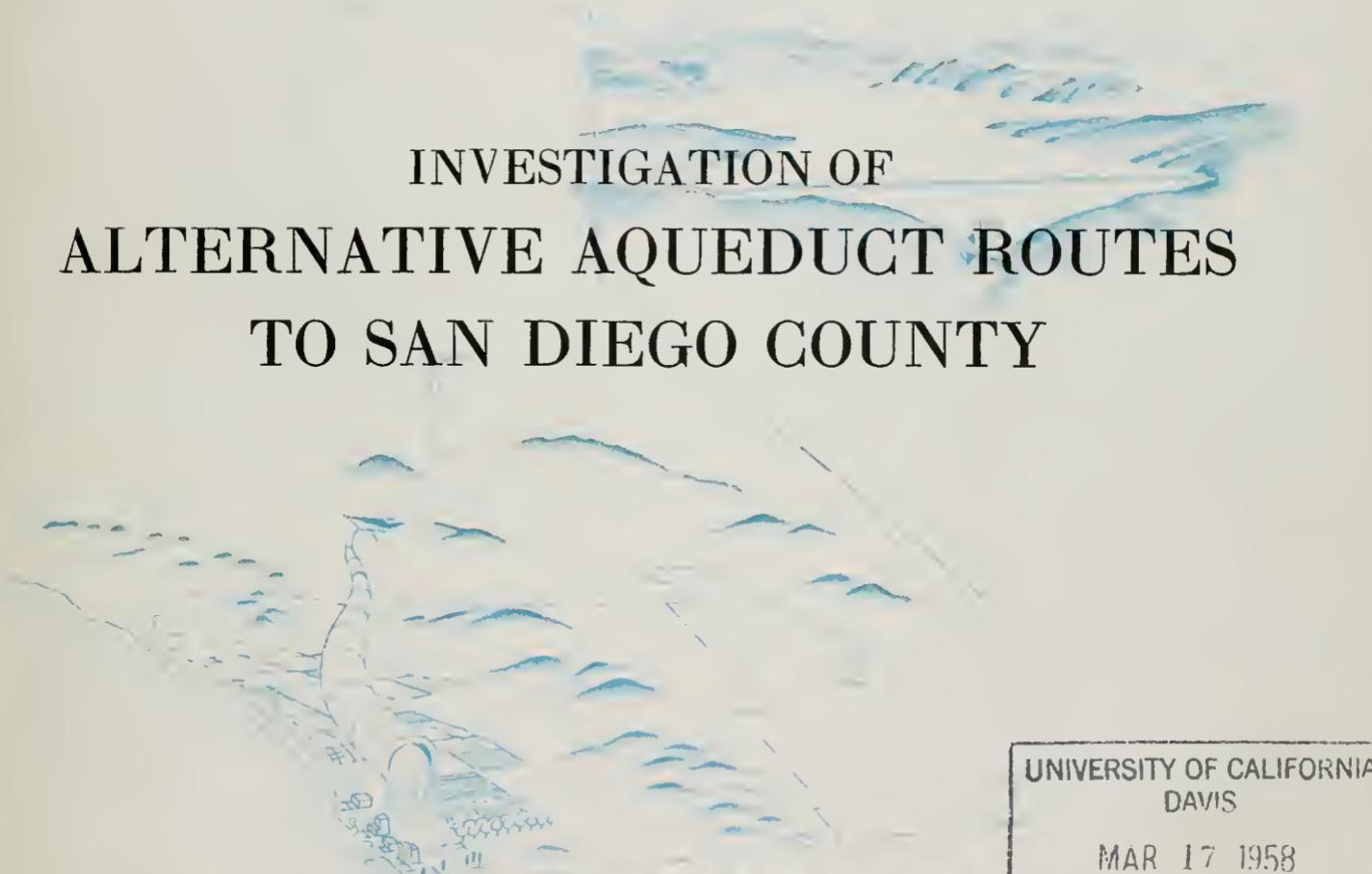
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BULLETIN No. 61
FEATHER RIVER PROJECT



INVESTIGATION OF
ALTERNATIVE AQUEDUCT ROUTES
TO SAN DIEGO COUNTY

PRELIMINARY
SUBJECT TO REVISION

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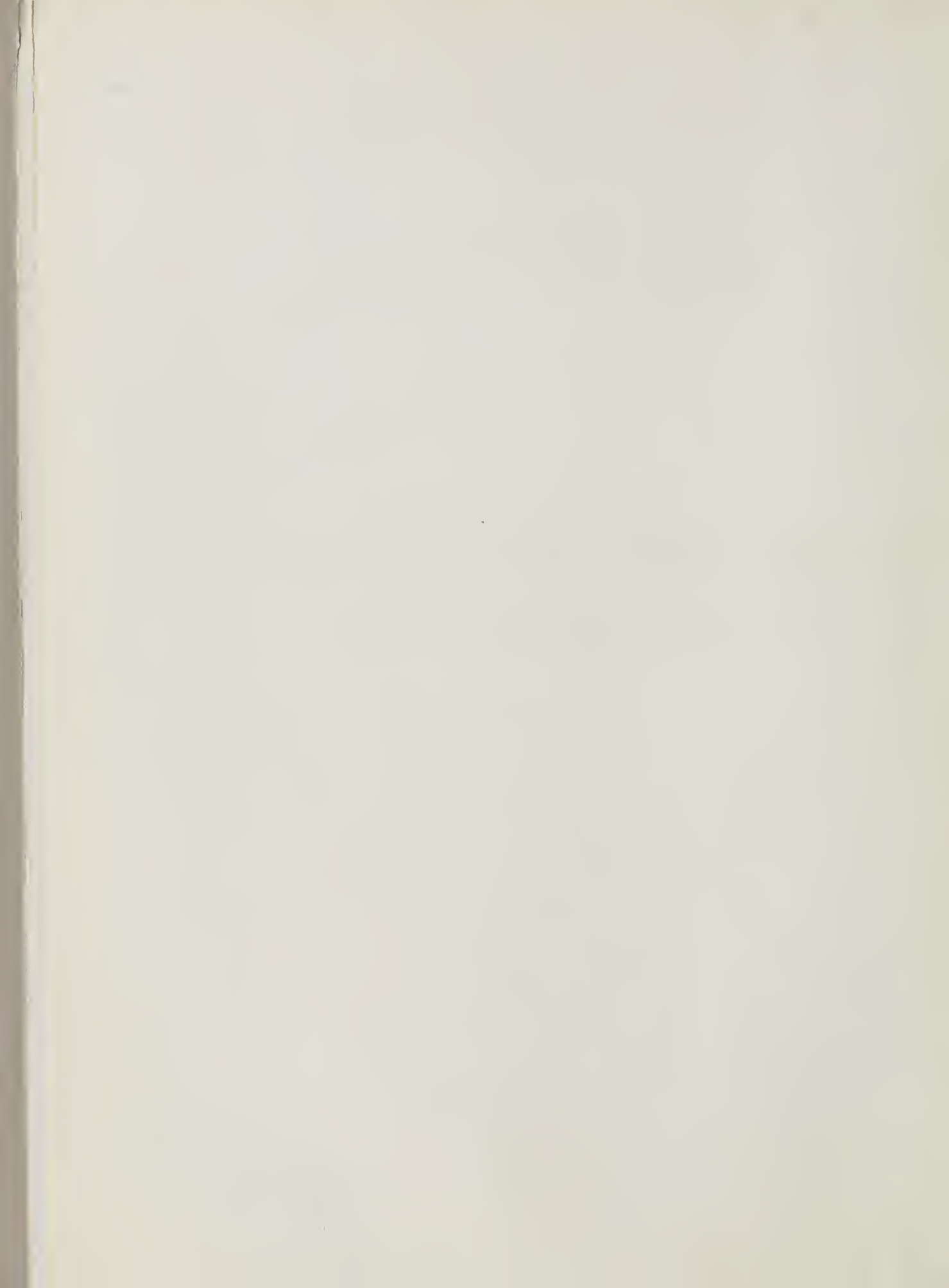
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Director of Water Resources

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STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF RESOURCES PLANNING

BULLETIN No. 61
FEATHER RIVER PROJECT

INVESTIGATION OF
ALTERNATIVE AQUEDUCT ROUTES
TO SAN DIEGO COUNTY

GOODWIN J. KNIGHT
Governor



HARVEY O. BANKS
Director of Water Resources

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March 1, 1957

Honorable Goodwin J. Knight, Governor, and
Members of the Legislature of the
State of California

Gentlemen:

I have the honor to transmit herewith Bulletin No. 61 of the Department of Water Resources, entitled "Feather River Project - Investigation of Alternative Aqueduct Routes to San Diego County". This investigation was authorized by the California Legislature of 1956, in Item 419.5 of the Budget Act of 1956, which appropriated \$200,000 for the work.

Work on this investigation was initiated in May of 1956, by the Division of Water Resources, the predecessor agency of this Department, through a provision in the budget act which made funds available prior to the beginning of the fiscal year. In view of the critical water supply situation in San Diego County, this investigation was conducted under an accelerated program in order to make available its findings at the earliest practicable date.

Bulletin No. 61 contains estimates of the probable future growth of population and irrigated agriculture and attendant demands for water therefor in San Diego and southwestern Riverside Counties, and presents recommendations as to the location and capacity of a new aqueduct to serve imported water to this area in conjunction with the existing two-barreled San Diego Aqueduct. The new aqueduct would convey presently surplus Colorado River water available to facilities of The Metropolitan Water District of Southern California near San Jacinto until Feather River Project water is available.

We are informed that The Metropolitan Water District of Southern California, together with the San Diego County Water Authority, plan on taking immediate action to construct an aqueduct along the route recommended herein but to a smaller capacity. It is recommended that in view of the estimated future demands for water in the potential service area of the proposed San Diego Aqueduct, and the relatively small increment in cost, that immediate steps be taken to construct the proposed aqueduct to the larger capacity as determined in this report.

Very truly yours,

HARVEY O. BANKS
Director

ACKNOWLEDGMENT

During the course of this investigation, valuable assistance and data were contributed by water service agencies in the investigational area. The Department of Water Resources gratefully acknowledges the cooperation of the following agencies:

Bueno Colorado Municipal Water District
California Water and Telephone Company
Carlsbad Municipal Water District
City of Escondido
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City of San Diego Water Department
Eastern Municipal Water District
Escondido Mutual Water Company
Fallbrook Public Utility District
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Lakeside Irrigation District
Poway Municipal Water District
Rainbow Municipal Water District
Ramona Irrigation District
Ramona Municipal Water District
Rincon del Diablo Municipal Water District
Rio San Diego Municipal Water District
San Diego County Water Authority
San Dieguito Irrigation District
San Marcos County Water District
Santa Fe Irrigation District
South Bay Irrigation District
Vail Ranch Company
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were contributed by the following pipe manufacturing firms:

American Pipe and Construction Company
Consolidated Western Steel Corporation
Kaiser Steel Corporation
Southern Pipe and Casing Company
United Concrete Pipe Corporation

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-----------------------------	---------------------------

ENGINEERING ADVISORY COMMITTEE

The Department of Water Resources appointed a committee of prominent engineers representing water service agencies and entities interested in water supply problems in the southern portion of the State to advise the Department on its alternative Feather River Project Aqueduct route studies. This Department gratefully acknowledges the assistance and advice generously contributed by the members of this committee during the course of this investigation. Members of this Engineering Advisory Committee are listed as follows:

<u>Name</u>	<u>Title</u>	<u>Sponsoring Agency</u>
. Louis K. Alexander	Vice President and Chief Engineer, Southern California Water Company	Board of Directors, West Basin and Central Basin Municipal Water Districts
. Paul Bailey	Engineer	Orange County Water District
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. Paul Beermann	Director, City of San Diego Water Department	City Council, City of San Diego
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. E. Fitzgerald Dibble	Chief Engineer, San Bernardino Valley Municipal Water Conservation District	Board of Directors, San Bernardino Valley Municipal Water District
. Robert B. Diemer	General Manager and Chief Engineer, The Metropolitan Water District of Southern California	Board of Directors, The Metropolitan Water District of Southern California
. George L. Henderson	Vice President, Kern County Land Company	Board of Directors, Kern County Farm Bureau and Board of Supervisors, Kern County

<u>Name</u>	<u>Title</u>	<u>Sponsoring Agency</u>
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Mr. Richard S. Holmgren	General Manager and Chief Engineer, San Diego County Water Authority	Board of Directors, San Diego County Water Authority
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Mr. Wallace C. Penfield	Consulting Engineer	Board of Directors, Santa Barbara County Water Agency
Mr. William S. Peterson	General Manager and Chief Engineer, Department of Water and Power, City of Los Angeles	Board of Water and Power Commissioners, City of Los Angeles
Mr. Brennan S. Thomas	General Manager and Chief Engineer, City of Long Beach Water Department	Board of Water Commis- sioners, City of Long Beach
Mr. Albert A. Webb	Consulting Engineer	Board of Directors, Western Municipal Water District of Riverside County

CHAPTER I. INTRODUCTION

San Diego County, one of the most rapidly developing areas in the nation, is presently faced with a critical water problem. The rapid growth of the County during a severe drought, now in its thirteenth year, has resulted in virtual depletion of local storage reserves and nearly full dependency on the two-barreled San Diego Aqueduct delivering Colorado River water from facilities of The Metropolitan Water District of Southern California near San Jacinto. This aqueduct is and has been, for some time past, operated almost continuously at full capacity. Only the occurrence of substantial runoff in local streams during the present winter season, to augment meager reserves of Colorado River water now in storage in local reservoirs, will prevent water shortages next year over much of San Diego County. Even with the advent of a sequence of years of above-normal precipitation and runoff, safe yield of existing water conservation facilities together with the supply of Colorado River water that can be obtained through the existing San Diego Aqueduct soon will be inadequate to meet the ever growing water needs of this area.

Authorization for Investigation

It was in recognition of this critical situation in San Diego County that the Legislature in Item 419.5 of its Budget Act of 1956 appropriated \$200,000 for surveys of alternative Feather River Project Aqueduct Routes to San Diego County. This item is quoted in full as follows:

"419.5--For surveys, explorations, investigations, preparation of construction plans and specifications; surveys of, negotiations for, and acquisitions of, rights of way, easements, and property, including other expenses in connection therewith, for the Feather River Project, as authorized by Section 11260 of the Water Code and as modified by the report of the Division of Water Resources of February, 1955, entitled "Program for Financing and Constructing the Feather River Project," and as may be modified subsequently, Water Project Authority 9,350,000

provided, that this appropriation shall remain available for expenditure until June 30, 1960; provided further, that, notwithstanding any other provisions of law, the appropriation made by this item may be expended to reimburse the Division of Water Resources Revolving Fund for expenditures incurred prior to July 1, 1956, which may be properly chargeable to this item; provided further, that \$3,550,000 of this item shall be used only for engineering and exploration work, and for acquisition of reservoir sites for the Alameda-Contra Costa-Santa Clara-San Benito branch aqueduct in Alameda, Contra Costa, Santa Clara and San Benito Counties; provided further, that \$500,000 of this item shall be used only for studies of alternative coastal aqueduct routes; provided further, that \$200,000 of this item shall be used only for studies of alternative aqueduct routes to San Diego County; provided further, that \$200,000 of this item shall be used only for location studies, surveys, engineering and exploration work for an aqueduct to service areas within west and south San Joaquin Valley, including Kern County. Any money in the Division of Water Resources Revolving Fund may be expended or encumbered for expenditure prior to July 1, 1956, or subsequent thereto, for preparation of working drawings, designs, plans or specifications for the project described in this item as to which reimbursement of the fund therefor is authorized by this item." (Emphasis supplied.)

In addition, Senate Concurrent Resolution No. 19, which is quoted following, contains certain provisions relative to the studies of alternative aqueduct routes to San Diego County:

"WHEREAS, The Division of Water Resources of the Department of Public Works has under consideration and study the selection of alternate aqueduct routes to San Diego County in connection with studies being made of the Feather River Project; now, therefore, be it

"Resolved by the Senate of the State of California, the Assembly thereof concurring, That the Division of Water Resources is requested in connection with its study to consider possible routes for such an aqueduct through San Bernardino County and Riverside County and to report thereon to the Legislature at its 1957 Regular Session; and be it further

"Resolved, That the Secretary of the Senate send a copy of this resolution to the Division of Water Resources and to the Director of Public Works."

Related Investigations and Reports

The investigation reported on herein is intimately related to prior investigational work of the former Division of Water Resources and other state water agencies on water problems and water resource developments in the State and to other current work under way by the Department of Water Resources. Reports and data available from these investigations were utilized in the preparation of this report. Use was also made of pertinent material and data contained in reports of other agencies.

The Feather River Project

The Feather River Project, the initial unit of The California Water Plan, was developed by the Division of Water Resources in 1951, in consideration of the impending need for additional water in the central and southern portions of the State, and also in recognition of the critical need for flood control on the Feather River. The project was originally outlined by the Division of Water Resources in State Water Resources Board "Report on Feasibility of the Feather River Project and Sacramento-San Joaquin Delta Diversion Projects Proposed as Features of The California Water Plan", May, 1951. Major units of the project included a multipurpose dam and reservoir on the Feather River near Oroville, a power plant at the dam, an afterbay dam and power plant, a Delta cross channel, an electric power transmission system, a conduit to transport water from the Sacramento-San Joaquin Delta to Santa Clara and Alameda Counties, and a conduit to transport water from the Sacramento-San Joaquin Delta to the San Joaquin Valley and to southern California. The aqueduct to southern California was contemplated as a "high line" route extending from the San Joaquin Valley in a tunnel through the Tehachapi Mountains at about elevation 3,300 feet. The aqueduct would then follow along the westerly side of the Antelope Valley, thence

through another tunnel into the South Coastal Area near the City of San Bernardino. From this point the aqueduct would extend to the south in a series of tunnels and siphons to a terminus in San Diego County at Horsethief Canyon a tributary of Cottonwood Creek, at elevation 2,854 feet.

The Feather River Project was authorized by the Legislature in 1951 by Chapter 1441, Statutes of 1951. This act also authorized and directed the Department of Public Works to conduct the necessary investigations, surveys and studies, and preparation of plans and specifications for the construction of the works authorized by the act and to submit the same to the Water Project Authority for its approval.

Further studies of the Feather River Project were continued by the Division of Water Resources until 1955, at which time a report entitled "Program for Financing and Constructing the Feather River Project as the Initial Unit of The California Water Plan", dated May, 1955, was submitted to the Legislature. It was concluded in this report that the project was engineeringly and financially feasible, and it was recommended that the Legislature appropriate funds to initiate its construction. This report recommended modifications of the original plan including the addition of the San Luis Reservoir on the west side of the San Joaquin Valley.

The foregoing report of May, 1955, also included analyses of alternative aqueduct routes to southern California including the afore-mentioned "high line" route and modifications thereof consisting of power drops to point of terminus near Castaic and San Bernardino, a long tunnel route at elevation 1,870 feet from the San Joaquin Valley to the South Coastal Area, and a coastal route commencing in the vicinity of Devils Den in the San Joaquin Valley and extending along the coastward side of the Coast Range through San Luis Obispo, Santa Barbara, and Ventura Counties, to a terminal reservoir near Castaic in Los Angeles County.

The 1955 Legislature appropriated \$250,000 to its Joint Committee on Water Problems for an independent study of the project. This committee employed Bechtel Corporation to perform the study. The results of the Bechtel Corporation independent review of the project were reported to the Committee in "Report on Engineering, Economic and Financial Aspects of the Feather River Project", December 31, 1955.

The Bechtel report found the project to be engineeringly and financially feasible and recommended among other things, further studies of the " ... High Line route via Castaic Creek power development and terminating in San Fernando Valley."

The Legislature of 1956, by the previously quoted budget item, appropriated \$9,350,000 for further work on the project including about \$1,100,000 for studies of alternative aqueduct routes to southern California.

The California Water Plan

The unprecedented development of California, with attendant increases in demands for water during World War II and the years immediately following, served to stimulate public concern over the State's water supply problems. The California State Legislature, in recognition of the growing State-wide water problem, by Chapter 1541, Statutes of 1947, directed the State Water Resources Board to conduct an investigation of the water resources of California, designated the "State-wide Water Resources Investigation". Funds were provided in the 1947-48 budget for commencement of the investigation and additional funds were provided through 1955 by subsequent Legislatures.

The "State-wide Water Resources Investigation" was conducted under direction of the State Water Resources Board by the Division of Water Resources. Three bulletins have been published pursuant to this investigation. Bulletin No. 1, "Water Resources of California", was published in 1951, and contains a

compilation of data on precipitation, unimpaired stream runoff, flood flows and frequencies, and quality of water throughout the State. Bulletin No. 2, "Water Utilization and Requirements of California", was published in June, 1955, and includes determinations of the present use of water throughout the State for consumptive purposes and presents forecasts of probable ultimate water requirements based in general on the capabilities of the land to support further development. The third and concluding phase of the State-wide Water Resource Investigation was reported on in Bulletin No. 3, "Report on The California Water Plan", published in preliminary form in May, 1956. This bulletin presents preliminary plans for the full practicable development of the water resources of the State to meet the ultimate water needs therein insofar as possible. The bulletin describes plans for local water resource development together with those works needed for the major transfers of water from the surplus areas of the north to the water deficient areas of the south, designated the California Aqueduct System.

As a result of the State-wide Water Resources Investigation, it was concluded that under conditions of ultimate development about 3,000,000 acre-feet of water annually must be delivered from northern California to the Southern Coastal Area to satisfy ultimate water requirements therein. This quantity of water would be in addition and supplemental to supplies obtained from maximum feasible local water resource developments and imported supplies available from the Mono-Owens System of the City of Los Angeles and through the Colorado River Aqueduct of The Metropolitan Water District of Southern California in the amounts of about 320,000 and 1,212,000 acre-feet per annum less losses, respectively.

With respect to the "San Diego Group", which includes San Diego County, a portion of southern Orange County, and southwestern Riverside County, it is estimated in Bulletin No. 3 that on the order of 1,300,000 acre-feet of

imported water will ultimately be required, which amount is greater than the total planned ultimate capacity of the Colorado River Aqueduct. Under The California Water Plan, the required supply of imported water would be delivered to this area by a high line aqueduct equivalent to the Feather River Project High Line route, previously described, by the existing San Diego Aqueduct, and by two additional aqueducts designated the Barona Aqueduct and the Second San Diego Aqueduct, all needed to accomplish delivery of the previously stated ultimate requirements for imported water in the area. The latter three aqueducts would extent southerly from the junction of an aqueduct, carrying northern California water, with the Colorado River Aqueduct of the Metropolitan Water District. At this junction water from northern California could be merged with the Colorado River water, and water from either source would be available for utilization in San Diego and southwestern Riverside Counties, and in the coastal plain areas of Los Angeles and Orange Counties.

The Barona Aqueduct would extend to a terminus in the proposed Barona Reservoir, and from San Jacinto south to the reservoir would generally parallel the existing San Diego Aqueduct to the east, but with a hydraulic gradient about 200 feet higher. The alignment of the Second San Diego Aqueduct was taken generally as that set forth in a report by the San Diego County Water Authority, described hereinafter, with a terminus in Lower Otay Reservoir south of the City of San Diego.

Studies of Alternative Feather River Project Routes to Southern California

Included in appropriations for the Feather River Project in the Budget Act of 1956, was about \$1,100,000 for work on aqueduct route studies for the Feather River Project generally south of Devils Den in the San Joaquin Valley. These studies have as their basic objective the determination of the most economical route or routes for delivering Feather River Project water into

southern California. As a basic premise in these studies, it is considered that the aqueduct should be constructed in the most economical location that will permit delivery of supplemental water to those areas of need that can afford to pay for project water and which are ready to contract for delivery and use of such water. In determination of the proper location for the aqueduct consideration must also be given to existing and proposed water supply facilities so that unnecessary duplication or overlap of such facilities will be prevented.

The Department of Water Resources is presently actively engaged in these alternative route studies under an accelerated program designed for completion of the studies and submission of a report to the Legislature thereon in 1958. The studies in San Diego County reported upon herein constitute a portion of this over-all investigation.

The alternative route studies include further detailed investigation of routes heading generally in the vicinity of Devils Den in the San Joaquin Valley and extending along the coast southerly to the South Coastal Area, studies of canal alignments and capacities in the San Joaquin Valley and of crossings of the Tehachapi Mountains. Further investigation is being made of the feasibility of utilizing off-peak energy for pumping required along considered aqueduct routes, and of generating hydroelectric energy during periods of peak energy demand in connection with the crossings of the Tehachapi Mountains. Studies are also being made and estimates prepared to determine the rate of increase in demand for water in the various component parts of the potential project service area in order to determine where and when project water will be needed in the southern California area and to select proper points of delivery for such water.

Other Related Investigations and Reports

In addition to the afore-mentioned comprehensive water resources investigations conducted by the Department of Water Resources and its predecessor agency, the Division of Water Resources of the Department of Public Works, information and data contained in certain other prior reports of the Division of Water Resources and in reports of other agencies were found to be of material value in the conduct of this investigation.

Of material assistance was the detailed planning work accomplished by the staff of the San Diego County Water Authority for the purpose of determining the source of supply, location, and capacity for a second aqueduct to San Diego, the results of which investigation are presented in "Report on the Probable Extent of Authority Area, the Amount and Source of Additional Water Supply Required, and the System Required to Efficiently Deliver Authority Water to the Agencies Comprising that Area", dated June, 1955. This report was reviewed by a Board of Engineers composed of Raymond A. Hill, John S. Longwell, and Carl R. Rankin, who presented the results of their review in "Report on Water Supply for Probable Future Developments in the San Diego County Water Authority", dated September 12, 1955. This latter report was also of great value to the Department of Water Resources.

The report of the San Diego County Water Authority concluded, among other items, that an aqueduct obtaining water from the facilities of The Metropolitan Water District of Southern California to the north should be constructed to a capacity of about 500 second-feet near the San Diego-Riverside County line, with an alignment extending southerly, to the west of the existing San Diego Aqueduct, to a point of terminus in Lower Otay Reservoir south of the City of San Diego. The Board of Engineers generally approved the location of the aqueduct but concluded that the capacity should be 200 second-feet. The

report of the Board of Engineers points out the limitation on availability of Colorado River water and the detrimental effects on its availability, which would result from construction of the Upper Colorado River Storage Project. The report also states that the most desirable point of delivery for Feather River Project water, from the standpoint of the San Diego County Water Authority, would be at the west portal of the San Jacinto Tunnel on the Colorado River Aqueduct.

During the course of the investigation, studies were initiated by The Metropolitan Water District of Southern California on an aqueduct southerly from their facilities near San Jacinto to the San Diego County line. Discussion with District officials and field data from a drilling program undertaken by the District were of material assistance to the Department of Water Resources.

Set forth in the following tabulation are other reports containing valuable material and data utilized by the Department of Water Resources in connection with the preparation of this report:

Board of Engineers, Caldwell, David H., Hyde, Charles Gilman, and Rawn, A M.
"Report on the Collection, Treatment and Disposal of the Sewage of San Diego County, California". September, 1952.

Boyle Engineering. "Proposed Water System for the Poway Municipal Water District". April, 1954.

Boyle Engineering. "Engineering Report to the Carlsbad Municipal Water District". June, 1955.

Boyle Engineering. "Proposed Water System for the San Marcos County Water District". June, 1955.

Boyle Engineering. "Engineering Report to the Valley Center Municipal Water District". July, 1955.

Burkholder, J. L., General Manager and Chief Engineer. "Report on the Need and Feasibility of Increasing the Capacity of the San Diego Aqueduct". San Diego County Water Authority. June, 1948.

California State Department of Public Works, Division of Water Resources.
"San Diego County Investigation". Bulletin No. 48. 1935.

California State Department of Public Works, Division of Water Resources.
"San Luis Rey River Investigation". Bulletin No. 48A. 1936.

California State Department of Public Works, Division of Water Resources.
"Report on Water Supply of La Mesa, Lemon Grove, and Spring Valley
Irrigation District in San Diego County". April, 1947.

California State Department of Public Works, Division of Water Resources.
"San Dieguito and San Diego Rivers Investigation". Bulletin No. 55.
1949.

California State Department of Public Works, Division of Water Resources.
"Santa Margarita River Investigation". Bulletin No. 57. June, 1956.

Helix Irrigation District. "Annual Reports". 1953 to 1955, inclusive.

San Diego County Water Authority. "Annual Reports". 1946 to 1955, inclusive.

State Council of Defense. "Report No. 3 San Diego Region". March, 1943.

United States Department of the Interior, Bureau of Reclamation. "Investi-
gation Design and Construction of the San Diego Aqueduct". 1948.

United States Department of the Interior, Bureau of Reclamation. "Report
on San Diego Project, Metropolitan Connection Enlargement". January,
1951.

United States Navy, Eleventh Naval District. "San Diego Aqueduct Project".
July, 1948.

Vista Irrigation District. "Annual Report and Financial Statement". 1955.

Water Department, City of San Diego. "Annual Report". 1954-55.

Objectives and Scope of Investigation and Report

Compliance with the spirit and intent of the legislation authorizing the investigation of alternative Feather River Project Aqueduct Routes to San Diego County necessitated consideration of aqueduct capacity and location consistent with the concurrent study of alternative Feather River Project Aqueduct Routes to southern California and the long-range objectives of The California Water Plan, and consideration of the recognized immediate critical water supply problem of the San Diego County area. The objectives and scope of this investigation were, therefore, designed to develop a program of aqueduct construction

that would comply with all of the foregoing considerations and thereby provide for both the present and future water needs of the San Diego County area.

General Criteria Affecting Aqueduct Location

The need for additional water in the San Diego County area is urgent, requiring immediate action to effect construction of additional aqueduct capacity at the earliest practicable date. At the present time there exists only one source of supplemental water for the San Diego County area, the presently surplus Colorado River water available at facilities of The Metropolitan Water District of Southern California.

On the basis of studies reported on herein, it is evident that, with provision for additional water, San Diego County and adjacent areas will exhibit substantial growth in the immediate future which will severely tax supplies available from existing sources including the Colorado River. It is also shown herein that the area with the greatest immediate growth potential is in the lower-lying coastal section of the County.

Further, it has been shown in State Water Resources Board Bulletin No. 3 that full satisfaction of the ultimate water requirements of the San Diego County area will require a physical connection between an aqueduct delivering northern California water and the Colorado River Aqueduct near San Jacinto, since these requirements are in excess of the planned ultimate capacity of the Colorado River Aqueduct.

It is thus apparent that construction of the next aqueduct to San Diego County from a connection with facilities of the Metropolitan Water District is logical not only with respect to the present critical situation but also with regard to the long range development of the area. Regardless of the route or routes finally selected for the Feather River Project leading from

northern California, the need for such water will be in that portion of the San Diego County area which could also be most readily served with Colorado River water.

In view of the foregoing, it was concluded that an aqueduct, which would serve Feather River Project water to the County, must, in the interim until such water is available, be capable of conveying presently surplus Colorado River water available at facilities of the Metropolitan Water District of Southern California near San Jacinto. This was adopted as a basic premise in this investigation.

Routes through San Bernardino and Riverside Counties

Senate Concurrent Resolution No. 19, previously quoted, directs that, in connection with studies of alternative aqueduct routes to San Diego County, possible routes for an aqueduct through San Bernardino and Riverside Counties are to be considered and a report thereon is to be submitted to the Legislature in its 1957 session. In compliance with this request, the Department of Water Resources has under way studies of alternative routes through San Bernardino and Riverside Counties from various points of entry for the Feather River Project Aqueduct into the South Coastal Area.

As previously mentioned, over-all studies to determine the most economical aqueduct route or routes for the Feather River Project into the southern California area either by a coastal route or via a high line route or modifications thereof through the Tehachapi Mountains are now under way. These studies are scheduled for completion in the spring of 1958, at which time a report will be submitted to the Legislature.

On the basis of preliminary work conducted to this time, it is concluded that determination of the location of the Feather River Project Aqueduct through San Bernardino and Riverside Counties must necessarily await completion

of the foregoing studies since location of this portion of the aqueduct is inherently dependent on the choice of the route south of Devils Den in the San Joaquin Valley and upon determination of points of delivery for project water in the southern California area.

Objectives

In consideration of the factors discussed in the preceding sections and in accordance with the intent of legislative directive, the principal objectives of this investigation may be summarized as follows:

1. Determination of the most economical route for an aqueduct which could serve Feather River Project water to the San Diego County area and, in the interim until such water is available, be utilized to deliver Colorado River water to the area.

2. Determination of the most economical capacity for this aqueduct to provide for the water needs of San Diego County and adjacent areas for a reasonable period in the future.

3. Determination of the cost of an aqueduct and appurtenant facilities consistent with (1) and (2).

Accomplishment of the foregoing objectives necessitated consideration of the following factors:

1. The magnitude and nature of the future demand for water in the potential service area of the aqueduct and the variation in such demand as may occur with aqueduct location and price of water. In this connection, it was assumed that water adequate in quantity and quality to satisfy estimated future needs would be available to the aqueduct, which assumption is consistent with the stated policy of The Metropolitan Water District of Southern California and with the objective of The California Water Plan.

2. Provision of maximum water service at minimum over-all cost requiring (a) comparison of the cost of alternative aqueduct routes giving proper consideration to cost of facilities necessary for regulation and conveyance of water to the service areas, and (b) evaluation of these routes from the standpoint of maximum integration with existing water supply facilities to avoid unnecessary overlap and duplication of such facilities.

Scope

The investigation of alternative Feather River Project Aqueduct Routes to San Diego County was initiated in May, 1956, through a provision in the budget act which made funds available to the predecessor agency of the Department of Water Resources, the Division of Water Resources of the Department of Public Works, prior to the beginning of the fiscal year. Subsequent to creation of the Department of Water Resources on July 5, 1956, work was continued by the Southern California District Office of that agency.

As an initial step in the investigation, the attempt was made to procure and analyze all prior pertinent information and data. Of particular value were discussions held with officials of the San Diego County Water Authority, from whom basic data relating to this agency's prior aqueduct studies were obtained.

Prior to detailed work on aqueduct costs and alignments, a complete study was made of future development as it will affect future demand for water in the potential aqueduct service area. In this connection, for the potential aqueduct service area the following studies were initiated simultaneously: projections of probable future population growth; economic studies of the future of irrigated agriculture, industry, and commerce; field studies of land use potential with reference to adaptability of the land to crops and to urban and suburban developments; studies of the ability to pay for water by crops

climatically adapted to the area; and review of unit uses of water by urban, suburban, and agricultural entities.

Personal contact was made by Department representatives with each major water service agency in the potential aqueduct service area to obtain the views of those experienced in water matters in the area on the potential for growth and increased water demand. These persons and entities were contacted at the initiation of the studies, during the course of the investigation, and subsequently after preliminary results had been obtained. In many cases, the valuable advice of such persons and agencies resulted in modification of preliminary values of future water demand.

Layouts for the several aqueduct routes considered together with estimates of cost therefor were prepared utilizing available U.S.G.S. topographic maps. These map studies were supplemented by field reconnaissance in order to refine selected alignments and to provide field data on materials classification and required structures. In certain instances where topographic coverage was deemed inadequate at critical structures, additional topography was obtained in the field.

Operational studies were made to ascertain the proper balance between aqueduct capacity and the location and capacity of regulatory storage reservoirs. These studies also considered the integrated operation of the existing San Diego Aqueduct and other systems serving the area with the new aqueduct. In this connection, the cost of major conveyance units from the aqueduct to serve areas of need was given consideration.

Study was given to the economics of various sizes and types of aqueduct, including reinforced concrete and steel pipe line as well as canal section, and also to the economics of staged construction of aqueduct facilities as demands for water dictated.

A detailed description of the investigation of alternative Feather River Project Aqueduct Routes to San Diego County and the results of the investigation are hereinafter presented in the three ensuing chapters. Chapter II, "Future Demands for Imported Water", describes the studies of and presents estimates for probable future growth of San Diego County and southwestern Riverside County, and the attendant demands for imported water therein. Chapter III, "Alternative Aqueduct Routes", describes the methods and procedures used in making economic comparison of alternative aqueduct routes leading to San Diego County, the results of the comparison, and a description of the location and features and estimates of cost of aqueduct facilities selected for immediate construction. Chapter IV, "Conclusions and Recommendations", contains conclusions and recommendations resulting from the investigation. Appended to the report are pertinent maps and graphical presentations of the results of the investigation, together with preliminary plans and profiles for the selected aqueduct route, and also typical preliminary designs of appurtenant aqueduct facilities, which were utilized in preparing the final cost estimate.

Detailed data and calculations, too voluminous for publication, are available in the files of the Southern California District Office of the Department of Water Resources.

Area of Investigation

In accordance with the basic objectives of the investigation, the principal area reported upon herein is that which could feasibly be provided water service from an aqueduct originating at facilities of The Metropolitan Water District of Southern California, between San Jacinto and Lake Mathews, and extending therefrom to San Diego County, and is hereinafter generally referred to as the potential aqueduct service area. This area comprises the southwesterly portion of Riverside County, generally south of the Colorado River Aqueduct, and that portion of coastal San Diego County lying, for the

most part, below elevation 1,700 feet. This is the area now facing a critical water shortage and that which was found to have the greatest immediate development potential.

In this investigation consideration was given to the possibility of development of water demands in the higher areas of San Diego and southwestern Riverside Counties lying above elevation 1,700 feet. Land classification surveys conducted during this and previous investigations indicate that there are irrigable and habitable lands in these higher areas. However, based upon preliminary engineering and economic studies, it was found that, because of their remoteness and elevation, these higher lands could not economically be supplied with water at this time from an aqueduct diverting from the Colorado River Aqueduct. Such lands would in the future receive water service from the previously described "High Line Aqueduct" under The California Water Plan.

The area investigated in Riverside County generally includes the southern portion of the San Jacinto Valley and the adjoining Perris, Menifee, and Domenigoni Valleys, and the Temecula and Pauba Valleys which drain to the Santa Margarita River. There are also some substantial areas of rolling hill land located north of Temecula Creek which are expected to have considerable economic importance in the future. Portions of this area, largely lands within Eastern Municipal Water District of Riverside County, presently support a highly developed agricultural economy.

The area investigated in San Diego County consists in large part of mountain or hill lands interlain by relatively slender stream valleys. The coastal segment is characterized by rolling hills and mesa lands, a substantial part of which has already experienced intensive development of both urban and agricultural nature.

The location of the area investigated is shown on Plate 1, "Location of Investigational Area". Also shown on Plate 1 are the locations of the

Features of the Feather River Project, as presently contemplated, and the facilities of the existing Colorado River Aqueduct of the Metropolitan Water District.

The climate in the San Diego Aqueduct service area is generally mild near the coast, with relatively light precipitation. Proceeding inland, as elevations increase, temperature variations become wider and precipitation becomes heavier. Mean seasonal precipitation is approximately 10 inches near the coast and in excess of 40 inches at the highest inland elevations of the tributary watersheds. Precipitation occurs principally in the winter months, with about 90 per cent of the seasonal total generally occurring during the months from November through April.

The principal streams draining the area include the San Jacinto, Santa Margarita, San Luis Rey, San Dieguito, San Diego, Sweetwater, Otay, and Tia Juana Rivers. Runoff in these streams is subject to wide variation from season to season and, because of the nature of its origin in precipitation, occurs almost entirely during the months from November through April.

Included in the area are the densely populated San Diego Metropolitan Area surrounding San Diego and Mission Bays and the less populous but rapidly growing communities of Escondido, Oceanside, Carlsbad, Fallbrook, and Rainbow. It is estimated that the population of San Diego County increased from about 550,000 in 1950 to more than 850,000 on January 1, 1957. About 700,000 of these people reside in the San Diego Metropolitan Area. The mild and equable climate in the area, of world-wide renown, has been and, it is believed, will continue to be a major factor in this rapid rate of population growth.

Agriculture, principally the raising of subtropical fruits, has expanded rapidly in San Diego County during recent years. Although the citrus industry in the South Coastal Area has declined in importance in recent years, the raising of avocados has expanded rapidly. The high monetary return from this crop permits payment of a relatively high rate for irrigation water.

Aircraft manufacture and fishing are major industries in the area. The capital investment in plants and equipment for these industries has almost doubled since 1950. In addition the headquarters of the Eleventh Naval District, including training, repair, air, supply, and radio facilities, are located in the San Diego Metropolitan Area, and Camp Pendleton, the largest Marine Corps base in the nation, is located near Oceanside.

In studies for preparation of The California Water Plan, it was determined that more than 70 per cent of the runoff of streams in San Diego County is controlled by existing surface and underground storage developments. The San Jacinto River, the only major stream in the Riverside County portion of the area, is essentially fully controlled. Because a high degree of control over runoff from most streams in the area is already being effected, further conservation of infrequent flood flows of these streams will necessitate construction of relatively large and expensive surface storage developments. Further, the yields obtainable from such developments are small when compared with the future water requirements of the area. It was determined in the studies of The California Water Plan that the probable ultimate seasonal supplemental water requirements of San Diego County, southwestern Riverside County, and southern Orange County (San Diego Group), are about 1,300,000 acre-feet, whereas the considered maximum practicable additional yield from storage developments that could be constructed on the streams in the San Diego Group would be about 60,000 acre-feet per season. It therefore becomes apparent that, in the future, additional development of local water supplies in San Diego County will be relatively insignificant and that additional facilities for importation of water from outside sources are vital to further development of the area.

Water supplies for the present water-using entities in the San Diego Aqueduct service area are derived from existing surface storage developments,

from importations of Colorado River water through the existing San Diego Aqueduct, and to a lesser extent by pumping from ground water storage. The safe seasonal yield of present water supply development is about 148,000 acre-feet, of which amount about one-half is from surface storage developments, with about 141,000 acre-feet per season being obtained through the existing San Diego Aqueduct. The existing facilities for development of surface water supplies and for importation of water from outside sources are shown on Plate 2 entitled "Major Existing Water Supply Facilities".

The major storage reservoirs in the area are listed in the following tabulation accompanied by data on their capacities and area of water service:

<u>Reservoir</u>	<u>Stream</u>	<u>Storage capacity, in acre-feet</u>	<u>Water in storage on 1-1-57 in acre-feet</u>	<u>Area served</u>
Morena	Cottonwood Creek	50,200	489	City of San Diego
Barrett	Cottonwood Creek	44,800	867	City of San Diego
Upper Otay	Proctor Valley Creek	2,800	288	City of San Diego
Lower Otay	Otay River	56,300	4,620	City of San Diego
Chollas	Trib. Las Chollas Cr.	310	292	City of San Diego
El Capitan	San Diego River	112,800	6,453	City of San Diego
San Vicente	San Vicente Creek	90,200	36,045	City of San Diego
Murray	Chapparel Canyon	6,000	3,452	City of San Diego
Sutherland	Santa Ysabel Creek	29,700	1,752	City of San Diego
Hodges	San Dieguito River	33,600	2,071	City of San Diego
San Dieguito	Trib. Escondido Creek	1,100	795	City of San Diego
Cuyamaca	Boulder Creek	12,000	0	Helix Irrigation District
Sweetwater	Sweetwater River	28,000	5,615	Chula Vista, National City
Loveland	Sweetwater River	25,000	1,500	Chula Vista, National City
Henshaw	San Luis Rey River	194,000	2,027	Vista, Escondido
Vail	Temecula Creek	<u>50,000</u>	<u>619</u>	Vail Ranch
TOTALS		736,810	66,885	

Water is imported to water service areas in San Diego and southwestern Riverside Counties through the existing facilities of the Colorado River Aqueduct and the San Diego Aqueduct, both of which are shown on Plate 2.

The initial features of the Colorado River Aqueduct were completed by The Metropolitan Water District of Southern California in 1941. The aqueduct consists of a series of pumping lifts and 242 miles of conduit leading from Lake Havasu on the Colorado River, westward across the Colorado Desert, passing through the San Jacinto Mountains in San Jacinto Tunnel and terminating at Lake Mathews about 12 miles southwest of Riverside. The aqueduct has an initial hydraulic grade line elevation of 450 feet at the Colorado River, a maximum grade line elevation of about 1,800 feet at Hayfield pump lift, and a grade line elevation of about 1,505 feet at the west portal of San Jacinto Tunnel. The initial facilities installed included only sufficient pumping units and siphon barrels to make possible the conveyance of a continuous flow of about 600 second-feet. During the past year, construction of additional works along the aqueduct have reportedly increased the capacity to about 1,000 second-feet.

During 1956, the Metropolitan Water District obtained authorization from the legislature and from the voters in the District for issuance of bonds in the amount of about \$85,000,000 to finance the construction and installation of pumping and siphon facilities necessary to provide ultimate conveyance capacity of the aqueduct of about 1,600 second-feet. The District proposes to complete this work in June, 1960.

The existing San Diego Aqueduct was constructed with two barrels of approximately equal capacity. The first barrel was constructed by the United States Navy and completed in 1947, as an emergency measure to provide water supplies made necessary by expansion of military and industrial installations and the attendant population increases resulting from World War II. The second barrel of the aqueduct was constructed by the U. S. Bureau of Reclamation and completed in 1954. Ownership and operation of the aqueduct were assumed by the San Diego County Water Authority by contract with the United States which provides for repayment of the construction costs by the former agency with partial

assistance of the Metropolitan Water District. The conveyance capacity of both barrels of the aqueduct under present operating conditions is in the order of 195 second-feet. During the 12-month period ending July 31, 1956, the aqueduct conveyed a total of 141,000 acre-feet or an average continuous discharge of 194 second-feet.

Surface storage developments constructed on streams draining the San Diego County area have a nominal safe yield of about 66,000 acre-feet per season. During the current and continuing drought, presently in its thirteenth year, storage in these reservoirs has been so depleted that the safe yield thereof will not be restored without the occurrence of substantial local runoff. As shown in a prior tabulation, the storage reserve on January 1, 1957, was about 67,000 acre-feet or about 9 per cent of the total storage capacity available, the largest portion of which was imported Colorado River water. The existing Colorado River Aqueduct is presently satisfying the bulk of the water needs of the area. Without substantial augmentation of storage in the reservoirs from local runoff, it is estimated that there will be a deficiency in water supply in the area of about 30,000 acre-feet during 1957. Even with restoration of the safe yields of the depleted reservoirs, anticipated rapid growth and attendant increase in water demand will so increase the water requirements in the San Diego County area, within two to three years, that the combined supply from the existing San Diego Aqueduct and local sources will be insufficient to satisfy demand thereon.

Responsible local agencies in the San Diego County area, recognizing this serious threat to their economy, are presently conducting an intensive campaign to conserve water. It is hoped by this campaign that the aforementioned water shortage, which would be largely felt in the northern San Diego County agricultural areas, will be somewhat mitigated.

Local Activity Relative to
Proposed Second San Diego Aqueduct

Since the initiation of this investigation in May of 1956, by the Division of Water Resources, certain actions relative to the financing and constructing of a second aqueduct to convey Colorado River water to San Diego County have been initiated by interested local agencies. In this connection, the Department of Water Resources addressed a letter dated January 3, 1957, to the Boards of Directors of The Metropolitan Water District of Southern California and of the San Diego County Water Authority, requesting a statement of their intentions regarding the financing and constructing of a second aqueduct to San Diego County. The letter is enclosed in Appendix A of this report.

Mr. Joseph Jensen, Chairman of the Board of Directors of The Metropolitan Water District of Southern California, by letter dated January 24, 1957, reproduced in Appendix A of this report, notified the Department of Water Resources of action of the Board of Directors with regard to construction of an aqueduct to San Diego County. The letter is quoted in part as follows:

"Following its consideration on January 22, 1957, the Board of Directors instructed me to inform you that it is the intention of this District to build an aqueduct to deliver additional water to the San Diego County Water Authority and that construction on it will begin within the present year.

"Previously, on January 8, 1957, your foregoing letter was referred to Mr. Robert B. Diemer, General Manager and Chief Engineer. His specific recommendations contemplate an aqueduct capable of delivering to San Diego County 180,000 acre feet of water a year, the first 16 miles from the point of diversion at the Colorado River aqueduct to Auld Valley to be open canal having a capacity of 500 cfs and the remainder to be a pipe line having a capacity of 250 cfs."

Mr. Richard S. Holmgren, General Manager and Chief Engineer of the San Diego County Water Authority, by letter dated January 29, 1957, enclosed in Appendix A of this report, notified the Department of Water Resources of adoption of a statement of policy by the Authority's Board of Directors,

attached to the foregoing letter, in which the Board, " ... urged the immediate construction of the Aqueduct by Metropolitan Water District; and support for a bond issue within the Authority area to finance the Authority's section of the Aqueduct." Mr. Holmgren's letter further notified the Department of Water Resources of action of his Board of Directors directing him to, " ... proceed with preparation of engineering plans and specifications for the Second Aqueduct along the westerly route, as set forth in the State's alternate aqueduct route study, subject to such modifications as may be desirable in the light of further engineering studies."

CHAPTER II. FUTURE DEMANDS FOR IMPORTED WATER

In order to select the proper route and capacity for the proposed San Diego Aqueduct from economic and engineering standpoints, it was necessary to give consideration to the timing, location, and magnitude of future demands for imported water in the potential aqueduct service area. A study was therefore made of the probable rate of increase in demand for water in San Diego and southwestern Riverside Counties, giving consideration to probable increases in population and irrigated agriculture and to factors influencing such growth. This chapter contains a description of this study and a summary of the results thereof.

In studies of future water demands, it was possible to take advantage of prior data compiled by the San Diego County Water Authority in connection with preparation of the previously mentioned reports of the Authority and of its Board of Consulting Engineers. Use was also made of material and data contained in the afore-mentioned Bulletin No. 2 of the State Water Resources Board, and Bulletin No. 57 of the Division of Water Resources.

Personal contact by Department representatives was made with officials of each of the major water service agencies in the investigational area to obtain the opinion of those experienced in water matters of the potential for growth and increased water demand therein. These persons and entities were contacted at the initiation of the studies, during the course of the investigation, and subsequently after preliminary results had been obtained. In many cases, the valuable advice of such persons and agencies resulted in modification of preliminary values of future water demand.

As previously stated, a basic premise in the studies of future water demands in the service area of the proposed San Diego Aqueduct was that water adequate in quantity and quality to satisfy future water needs therein would be

made available to existing and proposed import facilities. By this premise, it is assumed that growth and development in the potential water service area will not be inhibited by lack of a suitable water supply, but rather will be a function of other influencing conditions and factors, as hereinafter discussed.

Methods and Procedures

The general procedure followed in estimating future demands for imported water in San Diego and southwestern Riverside Counties consisted of the following steps:

1. An economic study of the area in order to evaluate the relationship of present levels of agricultural, commercial, and industrial development to the present magnitude and distribution of population and to the present extent of utilization of irrigable and habitable lands.
2. Extension of the economic study to estimate the potential for future development of irrigated agriculture, commerce, and industry in the area. This study included a detailed field classification survey of lands in the area to determine their adaptability to and availability for the various uses associated with future agricultural and urban and suburban enterprise.
3. Studies of present unit use of water by urban and suburban and agricultural developments in the investigational area and in comparable areas of the State and the nation and preparation of estimates of future unit uses of water for such developments.
4. Estimates of future population growth based on the economic factors evaluated under Items 1 and 2 together with employment of standard statistical methods of population projection.
5. Estimates of the areal extent of future irrigated agricultural lands based upon the afore-mentioned economic studies, with consideration given to the physical limitations of potential agricultural area by probable future

encroachment of urban and suburban development thereon, effects of ability to pay for water by climatically adapted crops, financing capacities of existing and proposed water service agencies, location of alternative aqueduct routes and costs of conveyance of water therefrom, and to other influencing factors.

6. Estimates of future water requirements in the potential aqueduct service area for each alternative aqueduct route investigated based upon (1) estimates of unit uses of water, (2) probable future population and area of urban and suburban development, and, (3) probable future areas devoted to irrigated agriculture. In this connection consideration was given to the firm water supplies available from local sources.

Estimates of future water needs in the potential aqueduct service area were developed for a 40-year period commencing in 1960 and extending until the year 2000. The year 1960 is considered the probable time of completion for a new aqueduct to be constructed to San Diego County. The 40-year period was considered to be of sufficient length to provide a basis for estimating long-term trends in water using developments, and to permit proper economic comparison of several alternative plans of aqueduct construction, both as to location and capacity. The forty-year period was selected for the purposes of analyses and has no significance with regard to the useful life of facilities hereinafter considered for construction nor with regard to the timing or availability of future imported water supplies.

For analytical purposes, all lands which it was considered might receive water service from the existing or proposed San Diego Aqueduct were segregated into 52 subareas, each of which was given individual study.

As stated in Chapter I, it was concluded, after preliminary reconnaissance, that only that portion of the investigational area generally lying below elevation 1,700 feet could feasibly be served water from the proposed San Diego Aqueduct. Therefore, analyses of certain of the higher and more remote of

the 52 subareas were not carried to the degree of refinement given to those subareas considered to be within the potential aqueduct service area.

The boundaries of the subareas were laid along the boundaries of presently organized local water service agencies wherever such agencies existed. The boundary locations of unorganized areas were adopted for study purposes on the basis of topographic features and geographical location of the lands, reflecting the physical problem of serving water thereto. An added influencing factor in selection of the subareas was their location relative to presently organized areas and the possibility of their eventual inclusion in such areas in order to take advantage of utilization of common water conveyance facilities. The foregoing subareas are listed by name and number in Table 1. The table also shows the gross area of each unit, the estimated areas of developable lands in each, and the approximate range of elevations of the lands contained therein. The estimated areas of developable lands in each subarea were derived from land classification surveys as reported in State Water Resources Board Bulletin No. 2, Division of Water Resources Bulletin No. 57, and the survey described hereinafter.

The subareas designated in Table 1 by numbers are identical to those utilized by the San Diego County Water Authority in its previously mentioned study and report of 1955. The subareas designated by letters are additional subdivisions of the investigational area defined by the Department of Water Resources during this investigation.

TABLE 1

GROSS AREAS AND AREAS OF DEVELOPABLE LANDS
IN SUBDIVISIONS OF THE WATER SERVICE AREA
OF THE PROPOSED SAN DIEGO AQUEDUCT

Subareas	:	Gross area,	Estimated net areas of developable lands, in acres	Range of elevation, in feet (U.S.G.S. datum)
Name	:Number:			
<u>San Diego County</u>				
San Diego Metropolitan Area		(225,000)	(225,000)	0-1,800
Rio San Diego Municipal Water District	5	19,400	19,400	300-1,000
Helix Irrigation District	6	30,000	30,000	300-1,400
South Bay and National City	7	17,100	17,100	0- 300
San Diego	12	76,300	76,300	0- 800
Otay Municipal Water District	16	60,000	60,000	100-1,800
Imperial	20	14,700	14,700	0- 400
Near Miramar	26	7,500	7,500	100- 400
Oceanside-Carlsbad Metropolitan Area		(43,360)	(34,820)	0- 500
Carlsbad Municipal Water District	2	20,630	16,480	0- 500
Oceanside	8	8,210	6,630	0- 400
Near Oceanside	27	14,520	11,710	0- 400
Escondido Metropolitan Area		(24,330)	(19,860)	600-1,500
Escondido	3	1,940	1,940	600- 800
Rincon del Diablo Municipal Water District	11	22,390	17,920	600-1,500
Santa Fe-San Dieguito Area		(24,090)	(18,790)	0- 300
San Dieguito Irrigation District	13	4,560	4,000	0- 300
Santa Fe Irrigation District	14	10,250	8,390	0- 300
East of San Dieguito	25	9,280	6,420	0- 300
Bueno Colorado Municipal Water District	1	51,700	36,210	200-1,700
Fallbrook	4	16,140	8,280	300- 900
Poway Municipal Water District	9	11,540	7,140	400-1,300
Rainbow Municipal Water District	10	35,390	22,200	200-1,100
Valley Center Municipal Water District	15	55,190	23,530	300-1,800
Ramona Municipal Water District	17	23,100	14,280	1,300-1,700
Rancho El Cajon	18	16,510	6,530	1,000-3,000
Pauma Valley	19	12,750	5,770	800-2,200
North of Santa Fe	24	9,530	4,750	100-1,000
South of Lake Hodges	28	32,880	13,040	100- 800
East of Del Mar	29	39,270	22,820	0-1,200
Lower Pauma Valley	30	25,290	8,430	200- 700
Camp Pendleton ^a		135,000	62,000	0-2,300
Camp Elliott ^a		38,000	17,000	300- 900
Jamul	A	75,160	17,780	500-3,000
Loveland	B	47,180	8,590	1,000-2,500
Potrero	C	31,370	6,530	2,000-3,500
Morena ^a	D	46,000	9,000	2,500-3,200

GROSS AREAS AND AREAS OF DEVELOPABLE LANDS
IN SUBDIVISIONS OF THE WATER SERVICE AREA
OF THE PROPOSED SAN DIEGO AQUEDUCT
(continued)

Subareas		Gross area, in acres	Estimated net areas of developable lands, in acres	Range of elevation, in feet (U.S.G.S. datum)
Name	Number			
<u>San Diego County (continued)</u>				
Live Oak ^a	E	25,000	9,000	3,000-4,000
El Capitan	F	111,810	13,470	1,000-4,000
Cuyamaca ^a	G	258,000	500	1,500-6,500
Rincon	H	33,580	10,220	400-1,700
San Vicente	I	70,000	13,890	700-3,000
South Sutherland	J	22,710	6,350	1,600-2,500
Guejito	K	75,190	19,740	1,000-3,500
Sutherland ^a	L	75,000	20,000	2,500-4,200
Henshaw ^a	M	69,000	11,000	2,700-4,300
Agua Tibia ^b	N	38,470	1,320	1,200-1,700
Palomar ^a	O	67,000	7,000	2,400-3,500
Chihuashua ^a	P	56,000	3,000	4,100-5,000
North of Pendleton ^a	W	35,000	4,600	500-1,000
Subtotals, San Diego County		1,782,540	712,460	
<u>Southwestern Riverside County</u>				
Temecula ^b	Q	24,120	1,920	500-2,200
Vail ^b	R	77,850	13,370	1,000-2,300
Murrieta ^b	S	71,360	22,330	1,000-1,800
Cottonwood ^b	T	83,510	8,530	1,600-2,800
Anza ^b	U	92,420	13,340	2,700-4,500
Winchester South ^a	V	86,000	60,000	1,400-2,100
Subtotals, Southwestern Riverside County		435,260	119,490	
GRAND TOTALS		2,217,800	831,950	

a. Data derived from State Water Resources Board Bulletin No. 2.

b. Data derived from Division of Water Resources Bulletin No. 57.

It will be noted in Table 1 that a number of subareas were combined into larger areas designated "Metropolitan Areas" in consideration of the probable nature of future development, and since after preliminary study, it was concluded that the economic aspects and water supply problems of the individual subareas were so closely related that evaluation on an individual basis would be unnecessary. These metropolitan areas were designated San Diego, Oceanside-Carlsbad, Escondido, and Santa Fe-San Dieguito. The boundaries of the foregoing subareas and metropolitan areas are delineated on Plate 3, entitled "Subdivisions of Investigational Area".

A systematic analysis was made of each subdivision of the investigational area, which analysis consisted of evaluation of eleven different factors which would affect the future growth and attendant demand for water therein. Data on these influencing factors were obtained from all available sources, including official records, published reports, personal interviews with officials of local, private, and governmental agencies, and field investigations and surveys by Department personnel.

The factors studied for each subarea are listed and discussed as follows:

1. Climatic Conditions - A mild, equable climate has played a major role in the development of the San Diego area. Large numbers of people have been attracted to the area by the climate and certain industries have moved in to take advantage of the available labor force. The long frost-free periods in certain portions of the area are favorable for the production of valuable subtropical fruits and other specialty crops, which has led to the development of intensive irrigated agriculture where water is available. However, since all parts of the investigational area are not equally well adapted to production of these valuable crops, each subarea was analyzed individually with regard to this factor.

2. Transportation Facilities - For urban development, a basic road system is essential. Also, good main highways, rail facilities, ship docking facilities, and airports all aid in the development of commerce and industry, which in turn stimulates further urbanization.

For agricultural development, a road system need not be as elaborate as in urban areas, and other types of transportation facilities essential to the urban community are not necessary to agricultural growth. However, as access must be provided into cultivated areas, existing roads enable development to occur more rapidly than if there were no such facilities.

3. Present Level of Urban and Agricultural Development - The present level of development determines to a large extent the rate of immediate growth, but becomes less important with the passage of time. There are in existence, in any extensively developed urban or agricultural area, utilities, roads, schools, commercial establishments, and other facilities required for servicing the needs of such areas. As between two areas with the same development potential, that area with the larger present economic base, with other influencing factors being equal, will exhibit the most rapid immediate growth. However, over a period of years, economic pressures will force the initiation of development in virgin lands, at which time the existing level of urban or agricultural development would be of relatively less importance.

Data obtained from field surveys, together with data appearing in State Water Resources Board Bulletin No. 2, were utilized to determine the relative levels of urban and agricultural developments in the various subareas, which determinations assisted in the projections of rate of growth for the immediate future.

4. Present Water Supply Facilities - The existence of facilities for development of local water supplies and for conveyance and distribution of local and imported water supplies are significant factors in the rapidity of future

agricultural and urban development with the importance of such facilities depending upon their present degree of utilization and capacity provided therein for future expansion. This factor would have a decreasing effect with the passage of time as does the present level of urban and agricultural development.

The existing water supply systems in each subarea were analyzed to determine the area served by such facilities, the capacities and present degree of utilization of such facilities and the possibilities of expansion inherent in their designs. These data were utilized, together with other factors, in estimating immediate rates of growth, but it was considered that this factor would have a negligible effect after about 1970.

5. Ability to finance Construction of Water Supply Facilities - The ability to finance construction of water supply facilities together with the factor discussed in Item No. 8, "Cost of Conveyance and Distribution Facilities" is basic to the evaluation of the probable growth rate of undeveloped areas. It is of lesser importance in highly developed areas with a large economic base and attendant financial capacity.

The present policy of the San Diego County Water Authority requires member agencies thereof to finance and construct all facilities for conveyance and distribution of water from the existing aqueduct to the individual service areas. In most instances, a general obligation bond issue is the only practical method of financing the construction of such facilities. Although the security for the bond issue, namely the value of lands to be developed, is generally relatively low until the development is accomplished, experience in the San Diego County area, as well as other parts of California, demonstrates that financing problems in undeveloped areas can be solved.

Analyses were made of those subareas with an apparent limited financial capacity for water supply development to ascertain assessed valuations and the probable present bonding capacity therein. It is recognized that

determinations of bonding capacity cannot be accurately evaluated, however, these analyses when compared with the estimated capital costs of delivering water from the considered aqueduct routes served as a guide in projecting probable rates of growth in certain areas.

6. Ability of Consumers to Pay for Water - Although to some extent influencing the amount of water used, the ability of consumers in urban and suburban areas to pay for water is not a major factor in the growth of such areas. This factor is, however, of prime importance in the development of irrigated agriculture along with the ability to finance construction of water supply facilities. The ability to pay for irrigation water is measured by the margin by which monetary returns from crops exceed all production, management, and marketing costs except the cost of water. A major consideration in the determination of ability to pay for water by future agricultural development is the cost of undeveloped land and the attendant costs necessary to prepare the land for irrigation. The ability to pay was evaluated for various types of crops considered to be adaptable to growing conditions in each of the subareas. This factor is discussed in greater detail in an ensuing section of this report.

7. Selling Price of Water - This factor is intimately related to the ability to pay for water. Charges for water have a major effect upon agricultural development but very little effect upon urban and suburban development, although a higher selling price for water usually will be a deterrent to location of industries with a high water usage. Since higher prices for water are usually found in water-short areas, public campaigns to conserve water, as well as the inhibiting effect of the price itself, have usually had the effect of lowering the unit use of water.

The actual cost of additional imported water supplies delivered to consumers in the service area of the proposed San Diego Aqueduct would reflect the price charged for water at the main aqueduct and the annual costs of

conveyance, pumping, and distribution facilities required to effect water delivery to the customer. This price would therefore vary among the several sub-areas and within a given subarea depending on aqueduct location.

The extent, if any, to which the selling price of agricultural water will be reduced by tax levies or by aid from urban and suburban water revenues will be a major factor in future development of irrigated agriculture. This selling price will depend therefore upon decisions of boards of directors of the various water service agencies involved and upon methods of service selected for the various subareas, and accordingly is not subject to finite determination at this time.

In order to ascertain the effect of price of water on the estimated future demand therefor, these estimates of water requirements were prepared for each considered aqueduct route with two assumed values for the cost of water delivered at the aqueduct. Water is presently sold to wholesaling agencies by the San Diego County Water Authority at a nominal price of \$12 per acre-foot with some additional regulatory storage charges in certain instances.

After consideration of local costs of conveyance and distribution of water incidental to providing delivery of water to the land, it appears that a price for water of \$40 per acre-foot at the main aqueduct for any of four alternative locations would result in a cost at the farmers' headgate which would generally approximate the estimated upper limit of ability to pay for water for the most lucrative types of agriculture. For analytical purposes, in this investigation the selling price of water delivered at the aqueduct was assumed to have a lower value of \$15 per acre-foot and an upper value of \$40 per acre-foot.

In the studies hereinafter described, the costs of delivery of the water to the land from the considered alternative aqueduct locations were added to the assumed wholesale prices at the aqueduct to obtain a unit price to be

compared with estimates of ability to pay for water. In this manner, those factors of price of water and ability to pay were utilized in determining the probable future demand for water in the potential aqueduct service area.

8. Cost of Conveyance and Distribution Facilities - This factor, as previously stated, is a basic consideration in projecting the rate of growth of water-using development, particularly of irrigated agriculture. Further, the effect of location of aqueduct on the growth of a given subarea is measured by the variance in cost of conveyance facilities from each considered route.

For each of the subareas preliminary estimates of the cost of conveyance and distribution facilities were prepared for each of the considered aqueduct routes. In this connection, reconnaissance-type estimated costs of construction and operation of the facilities were utilized. It should be noted that the estimates of cost so employed were only for the purpose of developing costs of delivery of water for comparison with estimates of ability to pay, and were not prepared to the same degree of refinement as those for facilities discussed in Chapter III of this report. Set forth in the following tabulation are unit costs used in the estimates.

Construction costs of main conveyance facilities
per acre-foot of maximum annual conveyance capacity

<u>Item</u>	<u>Cost per mile</u>	<u>Per cent of total</u>
Materials	\$ 4.20	60
Labor	1.40	20
Engineering, supervision and contingencies	1.19	17
Land - fee title and easements	<u>0.21</u>	<u>3</u>
Totals	\$ 7.00	100

Construction costs of distribution facilities
per acre-foot of maximum annual water delivery

<u>Item</u>	<u>Cost</u>	<u>Per cent of total</u>
Materials and labor	\$42.00	70
Engineering, supervision and incidentals	9.60	16
Reservoirs and appurtenances	6.00	10
Purification and miscellaneous expenses	<u>2.40</u>	<u>4</u>
Totals	\$60.00	100

In certain of the higher and more remote subareas, estimated costs of conveyance and distribution systems were in excess of the present or probable future capacity of these areas for financing such works. Further, costs of water delivered to land greatly exceeded the estimated payment capacity of climatically adapted crops. Such areas were not considered to be within the potential aqueduct service area and were eliminated from further detailed consideration.

Other less remote subareas which are presently undeveloped were found to have limited financing abilities that precluded the construction of distribution systems sufficient to serve all lands therein. However, in such areas, it appeared that, under a program of staged construction of distribution works, development of the areas would be possible. This factor was therefore taken into account in estimating the rate of development which would occur in such areas.

9. Industrial and Commercial Growth - The effect of industrial growth upon water demand can be direct if the particular activity has a high water-using characteristic or indirect because of the growth of population and agriculture which it might stimulate. Growth of industry in an area is dependent upon many of the factors previously itemized. Other factors are markets for products, availability of raw materials and a labor force, and a plentiful supply of water. This factor is discussed in greater detail in an ensuing section of this chapter.

10. Agricultural Growth - This factor is dependent upon many of the preceding items, particularly climate and cost of water. It was found that, based upon experience in this and other areas, where an adequate supply of water is made available at a cost within the upper limit of ability to pay for such water, the growth of irrigated agriculture has proceeded at a very rapid rate. This factor is also discussed in greater detail in an ensuing section of this chapter.

11. Local Political Environment - In some cases this is of more importance in water supply development than any other single factor. For example, some areas, wherein financial feasibility of water development facilities is marginal, will implement construction of the needed works through intense local enthusiasm for such development. Conversely, in other areas where ample capacity to finance water supply facilities exists, programs for water development will fail or never be initiated due to local apathy or desire to limit growth of population or industry. This factor is, by its nature, nebulous and difficult of evaluation and further will change with time. Throughout the area of investigation, the need for additional water supply development is well recognized at every level of government and among the lay population. In general it may be stated that "local political environment" in this area is conducive to rapid prosecution of a program of additional water supply development.

Classification of Lands for Water Service

The maximum limit to which irrigated agriculture or urban and suburban areas can develop is basically dependent upon the areal extent of lands available for these uses. Field surveys were conducted to classify lands in the investigational area with respect to their adaptability for various water-using developments. The purpose of these surveys was to establish the ultimate potential for irrigated agriculture and urban and suburban development based on availability

of land, and to evaluate the suitability of available land for these uses on the basis of those influencing factors susceptible of identification.

This survey was conducted generally throughout coastal San Diego County. Prior work of this nature done in connection with the preparation of State Water Resources Board Bulletin No. 2 was utilized within and adjacent to Eastern Municipal Water District of Riverside County and for the higher lands in San Diego County. Results of a similar survey conducted by the Division of Water Resources in 1953 and 1954 in connection with the Santa Margarita River investigation were employed in the Santa Margarita River watershed.

Certain portions of coastal San Diego County comprising lands within the military reservations at Camp Elliott and Camp Pendleton were not examined in the field in connection with this investigation, and basic data relative to their future water requirements were developed by other means as hereinafter described. Further, that portion of the area designated the "San Diego Metropolitan Area" is considered to be potentially an entirely urbanized area and was not examined in the field with respect to its land use adaptability. This area during the chosen 40-year period will contain irrigated agricultural land as it does at the present time. However, it is believed that the areal extent of such land will gradually decline with urban expansion.

As previously stated, it was found after preliminary reconnaissance that certain of the higher and more remote portions of the investigational area, from an economic or financial standpoint, could not be served with water from the proposed San Diego Aqueduct at this time. As a result, land classification surveys were not made in connection with this investigation in the Morena, Live Oak, Cuyamaca, Sutherland, Henshaw, Palomar, and Chihuahua subareas. Data on land classification in these latter areas hereinafter presented were derived from material presented in State Water Resources Board Bulletin No. 2.

The term "ultimate" as employed herein is referred to in the same sense as in publications of the State Water Resources Board and is defined as follows:

"Ultimate - This is used in reference to conditions after an unspecified but long period of years in the future when land use and water supply development will be at a maximum and essentially stabilized."

Methods and Procedures

All lands surveyed in the field were subdivided into various classes which reflected their suitability for production of different irrigated crops or for development of an urban or suburban nature. In all, 22 classes were employed, 16 for irrigated agriculture, 5 for urban and suburban lands, and 1 for forest lands.

For lands considered to have an agricultural potential, consideration was given to such physical characteristics as topography, soil depth, soil texture, saline or alkaline conditions, high water table conditions, and the presence of rock. Climatic conditions, while not a factor in the actual physical classification of the lands, were very important in development of the probable ultimate crop pattern therefor. This was particularly true in the case of subtropical fruits which are very susceptible to frost damage. For the purpose of planning for conditions of full development and, as stated, to ascertain the maximum limit of development, no consideration was given to those economic factors relating to production and marketing, which are variable among given areas and subject to considerable fluctuation over a period of years. Neither was the position of the lands relative to an immediately available water supply an influencing factor in the classification. However, both of these factors were given consideration in estimating the rate at which development could be expected to occur in the various areas.

In delineating the areas adjudged to be potentially urban or sub-urban rather than agricultural, consideration was given to their proximity to presently developed urban areas which could be expected to expand, the salubrious climate near the seacoast which would stimulate residential and recreational development, and to lands that would logically develop as urban center in areas of large irrigated agricultural potential.

Areas classified as adaptable to urban and suburban use were subdivided into several categories according to the type of development which could be expected to occur. These included: (1) intensively settled areas characterized by closely knit industrial, commercial, and residential development, (2) areas which probably would be primarily residential and which would contain those commercial establishments necessary to provide services to the resident population, (3) a combination agricultural and residential development which would include small acreages of agriculture together with residences, and (4) a low water-using type of development such as state and county parks, race tracks, etc.

Field mapping of all lands was done on aerial photographs having a scale of approximately 1:20,000. The area was covered by car, and at times by walking, as completely as roads and trails permitted. Road cuts, pits, and auger borings were examined to determine the effective root depth and texture of the soils. Representative slopes throughout the area were measured with a clinometer. By consideration of these factors, as well as the presence of rock, saline or alkaline soil conditions, and high water table, the appropriate class for each parcel of agricultural land was determined and delineated on the aerial photographs. In mapping the urban areas, factors affecting the probable type of such development were noted and evaluated in the field, and the proper classification assigned thereto. In this connection, prevailing topographical conditions were assessed for purposes of estimating probable maximum population densities.

Table 2 sets forth the standards for classification of lands for water service of the State Department of Water Resources which were employed in this investigation.

Areas of Land Use Adaptability Classes

Results of the land classification survey, together with data obtained from the afore-mentioned prior surveys, indicate that, of a total of approximately 2,330,000 acres in the investigational area, some 350,000 acres will probably eventually be urbanized and that about 510,000 acres are susceptible of intensive irrigated agricultural development. Of the remaining lands, about 173,000 acres in military reservations were not classified, and approximately 1,300,000 acres are not considered either irrigable or habitable.

Of the irrigable lands in the San Margarita River watershed and in the remainder of San Diego County surveyed in connection with this investigation, approximately 68,000 acres, or about 18 per cent are valley lands. Irrigable hill lands in this area amount to about 318,000 acres.

Most of the irrigable valley lands are found along the major streams of the area. Numerous smaller valleys and noncontiguous areas of flat land, some of which are on the coastal terraces, also contribute to this acreage. Practically all of these irrigable valley lands are composed of Recent alluvial soils and for the most part are of excellent agricultural quality. The topography is generally smooth and flat, or smooth and gently sloping, and is suitable for most types of irrigation practices. Textures vary from light to medium and there is ample effective root depth in nearly all cases. Some relatively small areas near the mouths of the streams are affected by concentrations of harmful salts. Since most of these irrigable valley lands occupy the lowest elevations in the valleys, the frost hazard is very great and practically precludes the production of subtropical fruits. These lands are best suited for the production of truck and field crops.

TABLE 2

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES

STANDARDS FOR CLASSIFICATION
OF LANDS FOR WATER SERVICE

Land : class:	Characteristics
V	Smooth lying valley lands with slopes up to 6 per cent in general gradient, in reasonably large-sized bodies sloping in the same plane; or slightly undulating lands which are less than 4 per cent in general gradient. The soils have medium to deep effective root zones, are permeable throughout, and free of salinity, alkalinity, rock, or other conditions limiting crop adaptability of the land. These lands are suitable for all climatically adapted crops.
Vw	Similar in all respects to Class V, except for the present condition of a high water table, which in effect limits the crop adaptability of these lands to pasture crops. Drainage and a change in irrigation practice would be required to affect the crop adaptability. For the purpose of this investigation it was assumed that there will be no future change in use of these lands.
Vs	Similar in all respects to Class V, except for the presence of saline and alkaline salts, which limits the present adaptability of these lands to crops tolerant to such conditions. The presence of salts within the soil generally indicates poor drainage and a medium to high water table. Reclamation of these lands will involve drainage and the application of additional water over and above crop requirements in order to leach out the harmful salts.
Vh	Similar in all respects to Class V, except for having very heavy textures, which makes these lands best-suited for the production of shallow-rooted crops such as rice and pasture.
Vl	Similar in all respects to Class V, except for having a fairly coarse textures and low moisture holding capacities, which in general make these lands unsuited for the production of shallow-rooted crops because of the frequency of irrigations required to supply the water needs of such crops.
Vp	Similar in all respects to Class V, except for depth of the effective root zone, which limits use of these lands to shallow-rooted crops, such as irrigated grain and pasture.
Vr	Similar in all respects to Class V, except for the presence of rock on the surface or within the plow zone in sufficient quantity to prevent use of the land for cultivated crops. These lands are suitable for irrigated pasture crops.

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES

STANDARDS FOR CLASSIFICATION
OF LANDS FOR WATER SERVICE
(continued)

Land : class:	Characteristics
Vhs	Similar in all respects to Class V, except for the limitations set forth for Classes Vh and Vs, which makes these lands best suited for the production of shallow-rooted, salt-tolerant crops.
Vls	Similar in all respects to Class V, except for the limitations set forth for Classes Vl and Vs, which makes these lands best suited for the production of deep-rooted, salt-tolerant crops.
Vps	Similar in all respects to Class V, except for the limitations set forth for classes Vp and Vs, which restrict the crop adaptability of these lands to shallow-rooted, salt-tolerant crops.
Vpr	Similar in all respects to Class V, except for the limitations set forth for Classes Vp and Vr, which restrict the crop adaptability of these lands to irrigated pasture.
H	Rolling and undulating lands with slopes up to a maximum of 20 per cent for rolling large-sized bodies sloping to the same plane; and grading down to a maximum slope of less than 12 per cent for undulating lands. The soils are permeable, with medium to deep effective root zones, and are suitable for the production of all climatically adapted crops. The only limitation is that imposed by topographic conditions, which affect the ease of irrigation and the amount of these lands that may ultimately be developed for irrigation.
Hl	Similar in all respects to Class H, except for having fairly coarse textures and low moisture holding capacities which in general makes these lands unsuited for the production of shallow-rooted crops because of the frequency of irrigations required to supply the water needs of such crops.
Hp	Similar in all respects to Class H, except for depth of the effective root zone, which limits use of these lands to shallow-rooted crops.
Hr	Similar in all respects to Class H, except for the presence of rock on the surface or within the plow zone in sufficient quantity to restrict use of the land to noncultivated crops.
Hpr	Similar in all respects to Class H, except for depth of the effective root zone and the presence of rock on the surface or within the root zone in sufficient quantity to restrict use of these lands to non-cultivated crops.

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES

STANDARDS FOR CLASSIFICATION
OF LANDS FOR WATER SERVICE
(continued)

Land : class:	Characteristics
Ht	Similar in all respects to Class H, except for topographic limitations. These lands have smooth slopes up to 45 per cent in general gradient for large-sized bodies sloping in the same plane, and slopes up to 12 per cent for rougher and more undulating topography. These lands will probably never become as highly developed as other "H" classes of land, and are best suited only for irrigated pasture.
Htl	Similar in all respects to Class Ht, except for having fairly coarse textures and low moisture holding capacities which in general makes these lands unsuited for the production of shallow-rooted crops and presents a great erosion hazard.
Htp	Similar in all respects to Class Ht, except for depth of the effective root zone, which limits use of these lands to shallow-rooted crops.
Htr	Similar in all respects to Class Ht, except for the presence of rock on the surface or within the plow zone in sufficient quantity to restrict use of these lands to noncultivated crops.
Htpr	Similar in all respects to Class Ht, except for depth of the effective root zone and the presence of rock on the surface or within the root zone, which limits use of these lands to noncultivated shallow-rooted crops.
U	Intensively developed urban lands presently used for residential, commercial, and industrial purposes.
R	Lands which are devoted primarily to presently developed residential areas, and which also contain those commercial establishments necessary to service them.
RV	Lands which are expected to be used for residential development, due primarily to their location near the coast or near intensively developed urban areas.
AR	Combination agricultural and residential areas which consist of very small acreages of agricultural development together with residences.
P	Areas having a very low water use such as state and county parks, fairgrounds, etc.
N	Includes all lands which fail to meet the requirements of the above classes.

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES

STANDARDS FOR CLASSIFICATION
OF LANDS FOR WATER SERVICE
(continued)

Land :	
class:	Characteristics
F	Presently forested lands, or lands subject to forest management, which meet the requirements for irrigable land but which, because of climatic conditions and physiographic position, are better suited for timber production or some type of forest management program rather than for irrigated agriculture.

Under the adopted classification standards, irrigable hill lands include those which fail to meet the requirements for irrigable valley lands with regard to topography, but which are suitable for irrigation development and for the production of certain crops with special irrigation practices. Since these lands are characterized by gently sloping or rolling to steeply sloping topography, air drainage is good and the frost hazard is minimized considerably. Hence, where soil depth and textures are favorable, they are highly valued for the production of subtropical fruits and off-season truck and flower crops.

Only a very small portion of these irrigable hill lands are found on Recent alluvial soils. Near the coast they occupy the old coastal terraces and slightly farther inland consist of residual soils derived from sedimentary and metamorphic rocks. Eastward from these areas are the residual soils derived from granitic rocks, which account for the greater part of the soils within the investigational area. Where climate permits, these granitic soils are by far the best suited of any in the area for the production of subtropical fruits, principally avocados.

The results of the classification survey for agricultural and urban lands are presented by subareas in Tables 3 and 4, respectively. Irrigable valley lands, irrigable hill lands, urban lands, and military reservations within the investigational area are shown on Plate 4, entitled "Classification of Lands for Probable Ultimate Use".

TABLE 3

CLASSIFICATION OF AGRICULTURAL LANDS IN
SAN DIEGO COUNTY AND SOUTHWESTERN RIVERSIDE CO.

(Areas in acres)

Subarea	V	Vw	Vs	Vl	Vp	Vr	Vpr	H	Hl	Hr	Hs	Ht	Htr	Htpr	Total
San Diego County															
San Diego Metropolitan Area															
Rio San Diego Municipal Water District	180	0	220	0	520	0	0	130	0	2,280	0	0	3,500	0	6,830
Helix Irrigation District	190	0	120	100	360	0	0	0	0	0	0	0	10	0	780
South Bay and National City	3,330	0	0	690	260	0	0	110	10	3,970	0	0	2,810	0	11,180
San Diego															
Otay Municipal Water District															
Imperial															
Near Miramar															
Oceanside-Carlsbad Metropolitan Area															
Carlsbad Municipal Water District	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oceanside	310	0	0	0	0	0	0	2,260	0	140	0	0	3,240	900	1,150
Near Oceanside															
Escondido Metropolitan Area															
Escondido	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rincon del Diablo Municipal Water District															
Santa Fe-San Diego Area															
San Diego Irrigation District	0	0	20	0	0	0	0	20	0	0	0	0	10	0	50
Santa Fe Irrigation District	130	0	0	30	0	0	0	10	0	110	0	0	30	210	980
East of San Diego	330	0	600	110	40	0	0	1,430	210	1,430	0	0	450	0	5,750
Bueno Colorado Municipal Area															
Water District	160	0	0	20	200	0	0	150	60	3,420	0	0	120	10	9,190
Fallbrook	30	0	0	0	0	0	0	630	0	60	0	0	2,320	0	3,100
Peway Municipal Water District	1,570	0	0	0	0	0	0	1,390	0	210	230	0	1,650	960	7,240
Rainbow Municipal Water District	820	0	0	1,480	80	0	0	1,600	100	5,140	0	0	2,640	0	24,500
Valley Center Municipal Water District															
Ranoma Municipal Water District	2,480	0	0	20	430	0	0	1,500	10	9,150	30	420	210	10,510	26,330
Rancho El Cajon	2,710	0	0	0	270	0	0	1,150	0	8,410	160	2,970	40	30	17,060
Pauma Valley	350	0	0	360	0	0	0	150	0	280	0	0	120	30	1,600
North of Santa Fe	1,000	0	0	1,080	0	0	0	2,240	60	90	640	90	230	100	6,860
South of Lake Hodges	0	0	0	0	0	0	0	10	0	1,500	0	140	0	230	6,170
East of Del Mar	340	0	0	210	0	0	0	3,630	0	590	70	1,150	2,510	1,470	16,110
	1,940	0	120	1,070	2,120	10	810	840	230	3,580	170	1,600	7,750	2,700	23,530

CLASSIFICATION OF AGRICULTURAL LANDS IN
SAN DIEGO COUNTY AND SOUTHWESTERN RIVERSIDE COUNTY
(continued)

(Areas in acres)

Subarea	V	V ₁	V ₂	V ₃	V ₄	V ₅	V ₆	V ₇	V ₈	V ₉	H	H ₁	H ₂	H ₃	H ₄	H ₅	H ₆	H ₇	H ₈	H ₉	Total	Irrigable
San Diego County (continued)																						
Lower Pauma Valley	1,300	0	0	1,940	40	250	0	710	0	1,360	1,910	130	90	2,320	100	250	10,400					
Jamul	840	0	0	410	70	0	0	1,200	350	4,690	20	60	60	11,110	0	1,520	20,330					
Loveland	210	0	0	0	130	0	0	570	0	3,470	110	280	190	5,000	90	1,070	11,120					
Potrero	690	0	0	40	20	10	0	1,850	20	630	440	170	40	1,820	60	2,780	8,570					
McKenzie																	9,000					
Levee Oak ^a	570	0	0	30	240	0	0	1,020	0	1,210	60	100	740	1,780	210	2,550	8,510					
El Capitan																	8,510					
Cuyamaca ^a																	500					
Rincon	1,700	0	0	980	0	50	0	1,160	50	1,950	150	80	1,060	1,290	1,050	3,770	13,250					
San Vicente	1,440	0	0	260	0	20	0	2,550	0	2,430	1,190	1,750	740	2,050	1,260	4,410	18,110					
South Sutherland	380	0	0	0	0	0	0	2,450	0	90	1,050	400	400	160	1,530	1,670	8,190					
Guejito	1,190	0	0	1,000	120	0	0	7,270	110	1,160	1,130	950	3,790	3,260	580	4,240	24,940					
Sutherland ^a																	20,000					
Henshaw ^a	50	0	0	0	0	0	0	350	0	160	220	10	130	570	40	150	11,000					
Agua Tibia ^b																	1,680					
Palomar ^a																	7,000					
Chinahuah ^a																	3,000					
North of Pendleton ^a																	4,600					
Subtotals, San Diego County	24,240	0	1,080	9,830	4,900	340	810	36,480	1,210	57,510	7,580	10,830	20,850	83,630	10,090	31,210	364,690					
Southwestern Riverside County																						
Temecula ^b	730	0	0	20	0	0	0	1,170	0	0	0	0	340	460	0	0	2,720					
Vail ^b	3,360	0	270	1,010	0	0	0	9,410	0	120	0	0	3,170	360	0	0	18,300					
Murrieta ^b	8,100	10	1,950	10	0	0	0	9,020	0	2,280	0	0	3,660	7,640	0	0	32,670					
Cottonwood ^b	2,410	0	140	1,140	0	0	0	6,360	0	1,130	0	0	110	880	0	0	12,170					
Anza ^b	5,610	50	0	1,210	0	0	0	11,230	0	10	0	0	60	980	0	0	19,150					
Winchester South ^a																	60,000					
Subtotals, Southwestern Riverside County	20,810	60	2,360	3,390	0	0	0	37,190	0	3,540	0	0	7,340	10,320	0	0	145,010					
APPROXIMATE TOTALS^c	45,100	100	3,400	13,200	4,900	300	800	73,700	1,200	61,100	7,600	10,800	28,200	94,000	10,100	31,200	509,700					

a. Data derived from State Water Resources Board Bulletin No. 2.

b. Data derived from Division of Water Resources Bulletin No. 57.

c. Excludes 173,000 gross acres in United States military reservations at Camp Elliott and Camp Pendleton.

TABLE 4

CLASSIFICATION OF URBAN LANDS
AND SUMMARY OF CLASSIFICATION OF LANDS

Subarea	U	R	RV	AR	P	Total : urban	Total : irrigable	F : lands	Lands not : susceptible : of urban or : agricultural : development :	Gross areas
San Diego County						225,000				225,000
San Diego Metropolitan Area										
Rio San Diego Municipal Water District										
Helix Irrigation District										
South Bay and National City										
San Diego										
Citay Municipal Water District										
Imperial										
Near Miramar										
Oceanside-Carlsbad Metropolitan Area										
Carlsbad Municipal Water District	550	30	11,790	0	0	12,370	6,830	0	1,430	20,630
Oceanside	1,110	230	5,600	0	50	7,090	780	0	340	8,210
Near Oceanside	0	0	3,100	0	0	3,100	11,180	0	240	14,520
Escondido Metropolitan Area										
Escondido	770	0	1,070	90	10	1,940	0	0	0	1,940
Rincon del Diablo Municipal Water District	0	20	10,790	950	30	11,790	8,230	0	2,370	22,390
Santa Fe-San Dieguito Area										
San Dieguito Irrigation District	260	270	3,050	490	0	4,070	50	0	440	4,560
Santa Fe Irrigation District	180	140	7,810	170	200	8,500	980	0	770	10,250
East of San Dieguito	0	0	1,910	0	0	1,910	5,750	0	1,620	9,280
Buena Colorado Municipal Water District										
Fallbrook	470	0	31,120	20	0	31,610	9,190	0	10,900	51,700
Poway Municipal Water District	270	10	6,110	0	0	6,390	3,100	0	6,650	16,140
Rainbow Municipal Water District	0	0	1,500	0	0	1,500	7,240	0	2,800	11,540
Valley Center Municipal Water District	0	0	3,140	0	0	3,140	24,500	0	7,750	35,390
Ramona Municipal Water District	0	0	3,010	0	190	3,200	26,330	0	25,660	55,190
Rancho El Cajon	360	0	250	0	0	610	17,060	0	5,430	23,100
Pauma Valley	0	0	7,280	0	0	7,280	1,600	0	7,630	16,510
North of Santa Fe	0	0	30	0	0	30	6,860	0	5,890	12,750
South of Lake Hodges	0	130	860	0	0	990	6,170	0	3,330	9,530
East of Del Mar	130	370	4,770	0	200	5,470	16,110	0	15,780	32,880
Lower Pauma Valley	0	0	0	0	0	0	23,530	0	10,270	39,270
Jamul	0	0	2,160	0	0	2,160	10,400	0	14,890	25,290
Loveland	0	0	0	0	0	0	20,330	0	52,670	75,160
Potrero	0	0	0	0	0	0	11,120	0	36,060	47,180
Morena ^a	0	0	0	0	0	0	8,570	0	22,800	31,370
Live Oak ^a	0	0	0	0	0	0	9,000	0	37,000	46,000
							9,000		16,000	25,000

CLASSIFICATION OF URBAN LANDS
AND SUMMARY OF CLASSIFICATION OF LANDS
(continued)

Subarea	U	R	RV	AR	P	Total urban	Total arable	F lands	Lands not susceptible of urban or agricultural development	Gross areas
San Diego County (continued)										
El Capitan	0	0	8,230	0	0	8,230	8,510	0	34,370	51,810
Cuyamaca ^a							500		257,500	258,000
Rincon	0	0	0	0	0	0	13,290	0	20,290	33,580
San Vicente	0	0	0	0	0	0	18,110	0	51,890	70,000
South Sutherland	0	0	0	0	0	0	8,190	0	14,520	22,710
Guejito	0	0	20	0	0	20	24,900	0	50,270	75,190
Sutherland ^a							20,000		55,000	75,000
Henshaw ^a							11,000		58,000	69,000
Agua Tibia ^b	0	0	0	0	1,470	1,470	1,680	380	34,940	38,470
Palomar ^a							7,000		60,000	67,000
Chihuahua ^a							3,000		53,000	56,000
North of Pendleton ^a							4,600		30,400	35,000
Subtotals, San Diego County	4,100	1,300	114,300	1,720	2,150	348,570	364,690	380	1,008,900	1,722,540
Southwestern Riverside County										
Temecula ^b	40	0	0	0	0	40	2,720	0	21,360	24,120
Vail ^b	0	0	0	0	0	0	18,300	0	59,550	77,850
Murrieta ^b	90	0	0	0	0	90	32,670	0	38,600	71,360
Cottonwood ^b	0	0	0	0	0	0	12,370	0	71,340	83,510
Anza ^b	0	0	0	0	0	0	19,150	0	73,270	92,420
Winchester South ^a							60,000		26,000	86,000
Subtotals, Southwestern Riverside County	130	0	0	0	0	130	145,010	0	290,120	435,260
APPROXIMATE TOTALS^c	4,200	1,300	114,300	1,700	2,200	348,700	509,700	400	1,299,000	2,157,800

- a. Data derived from State Water Resources Board Bulletin No. 2.
b. Data derived from Division of Water Resources Bulletin No. 57.
c. Excludes 173,000 gross acres in United States military reservations at Camp Elliott and Camp Pendleton.

Probable Ultimate Pattern of Land Use

Experience in California has shown that, even in the most intensively developed areas, not all irrigable lands receive water every year. Since results of the survey of irrigable lands were in terms of gross areas, the net areas that might ultimately be irrigated in any one season were determined by the application of appropriate percentage factors. These factors account for the effects of size and shape of parcels of irrigable lands, productive capacity of the lands and probable crop rotation, inclusions of small areas of non-irrigable lands within the irrigable lands, and inclusions of other land uses incidental to agricultural development such as roads, highways, and farm lots. The factors were largely based upon determinations previously made in intensively developed irrigated areas of the State, and on knowledge of the characteristics of the lands and proposed developments in the areas under consideration. The range in values for these factors is indicated in the following tabulation:

<u>Factors</u>	<u>Ratio of net to gross area, in per cent</u>	
	<u>Maximum</u>	<u>Minimum</u>
Size and shape of land	99	95
Inclusions of nonirrigable lands	99	94
Productive capacity and crop rotation	97	78
Rights of way	<u>95</u>	<u>93</u>
Resultant Percentage	90	65

Utilizing the data compiled from the survey and giving consideration to present irrigated agricultural development, present and indicated future trends in crop type, climatic conditions, and information gained from local farm advisors and other qualified agricultural agencies within the area, the probable ultimate crop pattern was projected.

Since avocados yield the highest net return of any irrigated crop produced in the area, it was anticipated that they would occupy practically all the acreage where conditions are favorable for their production. Flowers and off-season truck crops probably would account for a considerable acreage in the valleys where the frost hazard is too great for avocados. In some of the slightly colder areas, and on lands with heavier soils where lemons and limes produce reasonably well, it was considered that these crops would prevail.

In the areas not suited for avocado and citrus production, truck, field crops, deciduous fruits, and a limited acreage of alfalfa and pasture were projected as the probable ultimate crop pattern.

As in the case of agricultural lands, those areas classed as potentially urban contained inclusions of non-developable lands such as gullies, swamps, river beds, etc. Appropriate percentage factors, developed during the field survey, were applied to the gross urban areas to obtain the net habitable areas for purposes of estimating the probable ultimate pattern of urban land use.

The nature of the various potential urban areas as related to topographic characteristics, as well as geographical location and other previously mentioned factors, influenced the type of urban development projected for ultimate conditions.

Presented in Table 5 is the probable ultimate pattern of land use for the area surveyed during this investigation. Attention is directed to the fact that the land use pattern shown in Table 5 is for probable "ultimate" conditions of development as previously defined. In a later section of this chapter, the methods used in determining crop pattern and future population for the 40-year period herein considered will be described. Values for probable ultimate urban land use in Table 5 were used as a check on the reasonableness of the population projections.

TABLE 1

PROBABLE ULTIMATE PATTERN OF LAND USE IN
SAN DIEGO COUNTY AND SOUTHWESTERN RIVERSIDE COUNTY
(Net areas in acres)

Subarea	Agricultural lands										Urban lands			Unit's total
	: Alfalfa : : and :hay, grain, : : irrigated: and : : pasture :field crops:	: : : : : : : :	: Desiduous : : : : : : :	: Sub- : : : : : : :	: Total : : : : : : :	: Intensive: Rest- : : : : : : :	: : : : : : : :	: : : : : : : :	: : : : : : : :	: : : : : : : :	: : : : : : : :	: : : : : : : :	: : : : : : : :	
San Diego County														
San Diego Metropolitan Area														
Rio San Diego Municipal														
Water District														
Helix Irrigation District														
South Bay and National City														
San Diego														
Chay Municipal Water														
District														
Near Miramar														
Oceanside-Carlsbad														
Metropolitan Area														
Carlsbad Municipal Water														
District	0	0	980	0	3,990	400	5,370	550	10,560	0	0	11,110	16,480	
Oceanside	0	0	660	0	0	0	660	1,110	4,810	0	50	5,970	6,630	
Near Oceanside	200	0	3,450	0	4,710	800	9,160	0	2,550	0	0	2,550	11,710	
Esccondido Metropolitan Area														
Esccondido	0	0	0	0	0	0	0	770	1,070	90	10	1,940	1,940	
Rincon del Diablo														
Municipal Water District	0	0	670	200	5,600	200	6,670	0	10,270	950	30	11,250	17,920	
Santa Fe-San Dieguito Area														
San Dieguito Irrigation														
District	0	0	20	0	20	0	40	260	3,210	490	0	3,960	4,000	
Santa Fe Irrigation District	0	0	150	0	600	0	750	180	7,090	170	200	7,640	8,390	
East of San Dieguito	0	0	940	0	3,600	200	4,740	0	1,680	0	0	1,680	6,420	
Buena Colorado Municipal														
Water District	0	0	630	0	6,140	400	7,170	470	28,550	20	0	29,040	36,210	
Fallbrook	0	0	90	110	2,370	0	2,570	270	5,440	0	0	5,710	8,280	
Poway Municipal Water District	200	200	980	400	4,060	0	5,840	0	1,300	0	0	1,300	7,140	
Rainbow Municipal Water														
District	0	0	2,080	0	16,660	600	19,340	0	2,860	0	0	2,860	22,200	
Valley Center Municipal														
Water District	320	0	2,640	200	17,440	100	20,700	0	2,640	0	190	2,830	23,530	
Ramona Municipal Water														
District	1,100	900	4,810	1,700	5,160	0	13,670	360	250	0	0	610	14,280	
Rancho El Cajon	0	0	620	0	700	0	1,320	0	5,210	0	0	5,210	6,530	

Gross area classified as urban

PROBABLE ULTIMATE PATTERN OF LAND USE IN
SAN DIEGO COUNTY AND SOUTHWESTERN RIVERSIDE COUNTY
(continued)

(Net areas in acres)

Subarea	Agricultural lands										Urban lands				Unit
	: Alfalfa :	: Hay, grain, and pasture :	: Hay, grain, and pasture :	: Truck crops :	: Deciduous orchards :	: Sub-tropical flowers and vineyards :	: Tropical flowers and vineyards :	: Total agricultural :	: Intensive agricultural :	: Residential :	: Agricultural :	: Parks :	: Total urban :	: Total :	
San Diego County (continued)															
Pauma Valley	600	200	1,320	400	3,250	0	0	5,770	0	0	0	0	0	0	5,770
North of Santa Fe	0	0	200	0	4,530	0	0	4,730	0	20	0	0	0	20	4,750
South of Lake Hodges	300	0	1,280	1,000	9,430	300	0	12,310	0	730	0	0	730	0	13,040
East of Del Mar	600	0	3,990	100	13,270	400	0	18,360	130	4,460	0	200	4,660	0	22,820
Lower Pauma Valley	1,040	0	2,310	300	4,780	0	0	8,430	0	0	0	0	0	0	8,430
Jamul	610	200	900	600	13,480	0	0	15,790	0	1,990	0	0	1,990	0	17,780
Loveland	2,600	300	380	3,240	2,070	0	0	8,590	0	0	0	0	0	0	8,590
Potrero	3,180	300	410	1,940	700	0	0	6,530	0	0	0	0	0	0	6,530
Morana ^a								9,000							9,000
Live Oak ^a								2,000							2,000
El Capitan	970	300	1,000	2,010	2,080	0	0	6,360	0	7,110	0	0	7,110	0	13,470
Cuyamaca ^a								500							500
Rincon	700	300	1,640	600	6,980	0	0	10,220	0	0	0	0	0	0	10,220
San Vicente	620	300	1,690	900	10,380	0	0	13,890	0	0	0	0	0	0	13,890
South Sutherland	1,510	270	1,720	2,350	500	0	0	6,350	0	0	0	0	0	0	6,350
Guejito	2,690	300	4,880	3,900	7,360	0	0	19,730	0	10	0	0	10	0	19,740
Sutherland ^a								20,000							20,000
Henshaw ^a								11,000							11,000
Agua Tibia ^b	240	0	0	440	640	0	0	1,320	0	0	0	0	0	0	1,320
Palomar ^a								7,000							7,000
Chihuahua ^a								3,000							3,000
North of Pendleton ^a								4,600							4,600
Subtotals	17,480	3,570	40,440	20,390	151,100	3,400		300,480	4,100	101,480	1,720	680	332,980	635,460	
Southwestern Riverside County															
Tenequela ^b	980	200	400	300	0	0	0	1,880	40	0	0	0	40	0	1,920
Vail ^b	3,200	1,900	5,650	1,350	1,270	0	0	13,370	0	0	0	0	0	0	13,370
Murrieta ^b	7,140	4,200	6,800	3,000	1,100	0	0	22,240	90	0	0	0	90	0	22,330
Cottonwood ^b	3,830	2,100	1,700	900	0	0	0	8,530	0	0	0	0	0	0	8,530
Anza ^b	5,540	2,500	4,500	800	0	0	0	13,340	0	0	0	0	0	0	13,340
Winchester South ^a								60,000							60,000
Subtotals	20,690	10,900	19,050	6,350	2,270	0	0	119,360	130	0	0	0	130	0	119,490
APPROXIMATE TOTALS^c	38,200	14,500	59,500	26,700	153,500	3,400		419,800	4,200	101,500	1,700	700	333,100	752,900	

a. Data derived from State Water Resources Board Bulletin No. 2.

b. Data derived from Division of Water Resources Bulletin No. 57.

c. Excludes lands in United States Military Reservations at Camp Elliott and Camp Pendleton.

Unit Use of Water

Presented in this section is a description of methods and procedures used in determining present and probable future units of water use for the various subdivisions of the investigational area for both urban and agricultural purposes, together with a discussion of the monthly distribution of annual demands for water therein.

Urban Use

The projection of future urban water usage was based on estimates of population and per capita water consumption, since population was taken as the measure of urban growth.

In deriving per capita water consumption figures, no consideration was given to possible reuse of water applied for urban consumption. Population centers are now and probably will be for many years to come concentrated along the ocean, and sewage therefrom is largely discharged directly to the ocean. Inland communities not now discharging their sewage to the ocean are relatively small, and as they grow will probably construct ocean outfalls.

In order to determine trends in urban water use, analysis was made of available current and historical water consumption records for cities in San Diego County, southern California, and throughout the United States. The general conclusion reached as a result of this study was that per capita water consumption is exhibiting a definite increase. Definite determination of the amount of any increase is difficult since (1) populations of cities during periods between census years are indefinite, (2) water consumption figures usually do not include amounts of water produced, delivered, and consumed by entities other than the reporting agencies, and (3) significant amounts of agricultural usage of water are occasionally included in the statistics.

However, in consideration of all available data, it appears that per capita consumption has been increasing at a rate of about one per cent per year over that prevailing in the appropriate base period, usually in the 1940's.

In this investigation and in prior investigations by the Division of Water Resources and other agencies, it was found that use of water in urban areas is also affected by climatic conditions, economic conditions, level and type of industrial development and, to some extent, by the price of water. Per capita use of water tends to increase with distance from the ocean, with relatively higher average temperatures, and with relatively lower average precipitation. With other factors being equal, including price of water, the community with the higher per capita income will usually exhibit the higher per capita use of water.

Recent technological advances in household appliances have also tended to increase the per capita use of water throughout the country. These include automatic laundry facilities, dishwashers, and garbage disposals. The trend toward individual home ownership, with lawns and shrubbery which, in California, require frequent watering throughout a good part of each year, has also contributed to the increase in use of water. Many of these factors are a result of the general higher level of income prevailing in this country in recent years which has produced a higher standard of living. However, in view of imminent water shortages, certain cities, notably San Diego and Santa Barbara, have succeeded in maintaining a relatively low per capita use of water through public educational campaigns. It is believed that this low unit use of water is not only a result of efforts by individual citizens to reduce consumption but also the fact that industries having high water usage have not located in such communities.

The following tabulation presents per capita water consumption for 18 southern California cities and communities during 1955, five of which cities are

located in San Diego County. These data were obtained from the 1955 Annual Reports of The Metropolitan Water District of Southern California and the San Diego County Water Authority, and from the cities themselves.

<u>City or community</u>	<u>Water consumption in gallons per capita per day</u>
Anaheim	171
Beverly Hills	260
Burbank	213
El Cajon and La Mesa (Helix Irrigation District)	214
Escondido	170
Fullerton	215
Glendale	176
Los Angeles	161
National City and Chula Vista	188
Oceanside	179
Pasadena	215
San Bernardino	203
San Diego	126
San Marino	285
Santa Ana	123
Santa Barbara	150
Santa Monica	137
Torrance	141

It will be noted from the foregoing tabulation that the per capita water consumption in the cities of San Diego, El Cajon, La Mesa, National City, and Chula Vista, all of which are located in the San Diego Metropolitan Area, varied from 126 to 214 gallons per day. For purposes of estimating future water consumption in the San Diego Metropolitan Area, it was assumed that the overall per capita water consumption in this area would be approximately 140 gallons per capita per day in 1960, and that this rate of consumption would increase on a straight-line basis to 196 gallons per capita per day in the year 2000, which is an annual increase of 1.4 gallons per capita per day. This assumed increase is considered to be consistent with the afore-mentioned trend of increase in per capita water consumption.

For the Oceanside-Carlsbad Metropolitan Area and the Escondido Metropolitan Area, per capita water consumption for the year 1960 was assumed

to be slightly higher than that indicated in the tabulation for 1955 for the respective cities. This assumption is based on the fact that rural areas generally have a higher per capita consumption than do urban areas and each of these metropolitan areas contains a large rural population for which records of water use are not presently available. Values used for the year 1960 were 180 gallons per capita per day for the Oceanside-Carlsbad Metropolitan Area and 190 gallons per capita per day for the Escondido Metropolitan Area. These values were increased 1.4 gallons per capita per day per year up to a maximum of 200 gallons per capita per day.

For each of the other subareas, where it was considered that population growth would significantly contribute to water use, estimates of per capita water consumption were based on values developed for the Escondido and Oceanside-Carlsbad Metropolitan Areas.

Presented in the following tabulation are the unit values of water use employed in the several subareas:

<u>Subarea</u>	Water consumption in gallons per capita per day				
	<u>Year</u> 1960	<u>Year</u> 1970	<u>Year</u> 1980	<u>Year</u> 1990	<u>Year</u> 2000
San Diego Metropolitan Area	140	154	168	182	196
Oceanside-Carlsbad Metropolitan Area	180	194	200	200	200
Escondido Metropolitan Area	190	200	200	200	200
Santa Fe-San Dieguito Area	180	194	200	200	200
Bueno Colorado Municipal Water District	190	200	200	200	200
Fallbrook	190	200	200	200	200
Poway Municipal Water District	190	200	200	200	200
Rainbow Municipal Water District	190	200	200	200	200
Valley Center Municipal Water District	190	200	200	200	200
Ramona Municipal Water District	190	200	200	200	200
Rancho El Cajon	190	200	200	200	200
East of Del Mar	190	200	200	200	200
El Capitan	190	200	200	200	200
San Vicente	190	200	200	200	200

On the basis of historical records of use by personnel at Camp Pendleton, particularly during the recent years, unit water requirements for military personnel at Camp Pendleton and Camp Elliott were assumed to be 90 gallons per capita per day.

Agricultural Use

For many years, the Division of Water Resources conducted extensive studies of the use of water by irrigated crops. In addition, many additional studies of this nature have been made by other agencies in California and in the western United States. Included in these investigations were studies of use of water correlated to the influencing factors of climate, crop type, soil type, and method of irrigation. In connection with the preparation of State Water Resources Board Bulletin No. 2 and in special investigations in critical areas conducted by the State Water Resources Board, studies were made of consumptive use of water and amounts of water applied to irrigated crops throughout the State. For purposes of this investigation, units of water use for irrigated agriculture developed for Bulletin No. 2 were reviewed and compared with more recent available data recorded by water service agencies operating in the investigational area. Consultation was held with officials of these water service agencies and with individuals in the area and in certain instances, values of water use presented in Bulletin No. 2 were modified to reflect local conditions. In general, however, Bulletin No. 2 data were adopted as representative of use of water by irrigated crops in the investigational area.

In studies of the San Diego County area for Bulletin No. 2, determinations of ultimate agricultural water requirements, that is, the amounts of water excluding precipitation needed to provide for use of water by irrigated crops and for all irrecoverable losses incidental to such use, were based upon the assumption that a certain proportion of the unconsumed residuum of water applied for agricultural use would return to underlying ground water storage or to stream channels where it would be available for reuse. In connection with this investigation, units of applied water were taken as the measure of agricultural water requirements thereby giving no credit to such reuse. By this assumption,

estimates for water requirements so derived would be on the high or conservative side. This assumption is considered reasonable inasmuch as the units of irrigation water use so employed are relatively low as compared to other portions of the State, and it is probable that little return flow would be available for re-use. Further, a large portion of the lands that would be served from the proposed San Diego Aqueduct are located close to the ocean so that there is little opportunity for downstream capture of return flow. Under full development conditions with irrigation of substantial areas of inland portions of the County, return flow would constitute a significant source of water supply as was assumed in Bulletin No. 2.

Units of water use adopted for irrigated crops were varied in accordance with prevailing practice and reflect the difference in water application between the inland and coastal areas. For example, it was found that for citrus and avocados the annual depth of applied water varied from as little as one and a half acre-feet per acre near the coast to two and a half acre-feet per acre in the interior areas.

As previously stated, studies of the probable future nature of irrigated agriculture in the potential aqueduct service area indicate that the crop pattern will largely consist of citrus and subtropical fruits and truck and field crops. Unit uses of water were determined for two general crop categories including citrus and subtropical fruits in one category and truck and field crops in the other, as shown in the following tabulation:

<u>Subarea</u>	<u>Units of water use in acre-feet per acre per year</u>	
	<u>Citrus and subtropical orchards</u>	<u>Truck and field crops</u>
San Diego Metropolitan Area	1.9	2.0
Oceanside-Carlsbad Metropolitan Area	1.5	1.8
Escondido Metropolitan Area	2.5	2.5
Santa Fe-San Dieguito Area	1.7	3.0
Bueno Colorado Municipal Water District	1.5	1.5
Fallbrook	2.0	1.9
Poway Municipal Water District	1.5	1.5
Rainbow Municipal Water District	2.5	2.5
Valley Center Municipal Water District	2.0	2.0
Ramona Municipal Water District	2.3	2.0
Rancho El Cajon	2.3	---
Pauma Valley	2.0	---
North of Santa Fe	2.1	---
South of Lake Hodges	2.3	2.4
East of Del Mar	1.5	1.5
Lower Pauma Valley	1.5	2.0
El Capitan	2.3	2.3
Rincon	2.2	2.3
San Vicente	2.3	2.3
Agua Tibia	2.3	2.0
Camp Elliott	---	---
Camp Pendleton	---	---
Temecula	---	1.5
Vail	2.0	2.0
Murrieta	2.0	2.0
Winchester South	---	2.0

Monthly Distribution of Annual Water Demands

The monthly distribution of future annual water demands will vary appreciably for the various subareas herein considered, depending upon the relative magnitudes of future agricultural and urban water uses therein.

Monthly demand for irrigation water may vary from little or none during winter months to more than 15 per cent of the seasonal total during a dry summer month. The monthly distribution of annual irrigation water demand varies with the crop, soil type, and distance from the coast. Urban water demands are substantially higher during summer months than during winter months but they exhibit greater uniformity throughout the season than those for

irrigation. The following tabulation presents estimates of average monthly distribution of annual water demands for irrigated agriculture and for urban areas in the South Coastal Area as shown in State Water Resources Board Bulletin No. 2:

<u>Month</u>	Monthly demand in per cent of annual demand	
	<u>Irrigated agriculture</u>	<u>Urban areas</u>
January	2.7	6.4
February	2.2	6.4
March	3.8	7.0
April	6.5	8.0
May	10.9	9.1
June	12.8	9.8
July	13.7	10.8
August	13.6	10.6
September	12.5	9.6
October	9.5	8.4
November	7.2	7.3
December	<u>4.6</u>	<u>6.6</u>
Totals	100.0	100.0

As previously indicated, future development in the various subdivisions of the service area of the proposed San Diego Aqueduct is expected to be of both urban and agriculture nature. Therefore, it is expected that the monthly distribution of future water demands in the various subareas will generally be a composite of the extreme values shown in the foregoing tabulation.

The future monthly distribution of water demands for each of the subareas herein considered was estimated generally from experience records of water service agencies presently operating therein where such records were available. Subareas having similar patterns of estimated future development with regard to the relative extent of agricultural and urban areas therein, giving consideration also to climatic conditions, were divided into seven general groups. For each of these groups a pattern of monthly distribution was developed from the records of one or more water service agencies which presently serve areas having land use patterns similar to those projected for the year 2000 for the areas

comprising the group. The data so developed are presented for each of the seven groups on Plate 8, entitled "Estimated Monthly Distribution of Demand for Water in Per Cent of Annual Demand in Year 2000".

Estimated Future Population

The determination of future water requirements for urban and suburban lands was based upon estimates of future population growth. Probable future population growth was estimated by statistical projections tempered by studies of anticipated industrial and commercial growth of the area, and by land classification studies previously described which defined the availability of land for urban expansion. Presented in this section is a discussion of the probable future of industry and commerce of the area and a description of the methods and procedures employed in and the results derived from studies of future population growth.

Early in the course of this investigation, it was found that the rate of growth of population and urban expansion was not influenced by aqueduct location. This resulted from the fact that existing and potential urban areas in the County are located reasonably close to each of the considered aqueduct routes, thereby minimizing the problem of financing construction of conveyance and distribution systems. Further, since the effect of selling price of water on rate of urban expansion was not considered to be a deterring factor, the influence of aqueduct location in this regard could be neglected.

Industrial and Commercial Growth

Industrial and commercial growth is not expected in itself to create major increases in demands for water in the service area of the proposed San Diego Aqueduct, but is expected to stimulate expansion of population. The industries presently operating in the area are generally associated with

electronics, aircraft manufacturing, missile manufacturing, and research, which in general are not high water using industries. This trend is expected to continue in the future.

The importance of a broad industrial base to population growth may be seen in nationwide statistics, which indicate that every employed person supports about 2.6 persons including himself. When people are engaged in manufacturing or interstate commerce, their earnings become a source of revenue for local commerce and service industries, which in turn are able to support about an equal number of persons. On this basis, about 5.2 persons can be adequately supported by the earnings of each person obtaining income from outside the area. Local businesses are also stimulated by industries and commercial enterprises through direct purchases of parts, supplies, and services. It is characteristic of industry and commerce that they build upon each other.

It is, therefore, seen that industrial and commercial growth directly influences population growth. Further, the increase of population creates a demand for food which in turn stimulates the development of agriculture.

During the period generally prior to 1940, growth of industry and commerce in San Diego were hampered by the area's general remoteness with resultant high transportation charges added to all imported raw materials and exported finished products. San Diego County grew during this period, in spite of the absence of a broad industrial base, principally through the advantages it offered to retired persons. Subsequent to 1940 with the advent of World War II, expansion of military facilities and associated industries substantially enlarged the economic base and population of the City of San Diego and its environs. During the late forties and early fifties, the continued growth of population in the San Diego area and in California has resulted in creation of markets for its goods within competitive shipping distances.

The presence of several large military installations, including the Eleventh Naval District Headquarters, with a present staff of some 35,000 persons, and Camp Joseph E. Pendleton, the largest Marine Corps installation in the nation with a present complement of about 50,000 personnel including one complete division, continues as an important factor in influencing the type and extent of industry and commerce, and in turn, population in the San Diego area.

Through consultation with informed people in the area, information was obtained on contemplated new industry therein. Because of the difficulty of making finite projections of future industrial growth and of correlating such projections with estimates of population growth, it was not possible to utilize the information so obtained quantitatively. However, it was of great value in supporting statistical projections of population growth and attendant agricultural expansion. The information was also of value in resolving questions of relative geographic location of future concentrations of population in the various parts of the area.

Although San Diego County is not generally looked upon as a major industrial area, statistical data indicate that during the past 15 years, there has been a rapid increase in industrial activity therein, particularly in the San Diego Metropolitan Area. Because of its strategic location from a national defense standpoint and because of the existence of several large military installations, this expansion of industry reached a high peak during World War II. After a brief slump in activity following cessation of hostilities, a strong rally in industrial expansion occurred which has continued to the present time.

The following tabulation shows the increase in numbers of employed persons in the San Diego Metropolitan Area engaged in manufacturing and industrial activities which market their products largely outside the area, and therefore may be considered to draw their income from outside sources.

<u>Year</u>	<u>Employed persons</u>
1940	24,500
1950	34,750
1956	56,250

The previously mentioned personnel of the U. S. Navy and U. S. Marine Corps bring the present total of persons receiving income from sources generally outside of the County to about 140,000. In addition to these are the retired persons who are continuing to move into the area because of its desirable climate and location and who bring into the area a substantial amount of income from outside sources.

The increase in numbers of persons employed in local industry and commerce who, in general, have their primary sources of income within San Diego County is illustrated by the following tabulation:

<u>Industry</u>	<u>Number employed</u>		
	<u>1940</u>	<u>1950</u>	<u>1956</u>
Trade-wholesale and retail	21,280	43,600	52,900
Service industries	27,277	40,350	47,800
Construction	5,724	15,000	15,300
Finance, insurance and real estate	not avail.	7,300	9,700
Transportation, communications and utilities	4,634	9,550	11,800
Government (exclusive of naval and military, generally state and local)	not avail.	<u>25,550</u>	<u>27,000</u>
Totals		141,350	164,500

Based on information obtained from officials of local Chambers of Commerce and banking and service organizations, there is every reason to believe that the foregoing growth of industry and commerce will continue into the future. In general, new industry in San Diego County consists of the manufacturing of electronic equipment, instruments, and plastics, much of which is associated with aircraft manufacturing. These industries will be able to compete on the national market, in spite of the general remoteness of the area, because the products involved have high ratios of cost to weight which reduces the importance of shipping costs.

The General Dynamics Corporation (Convair) operates an extensive aircraft fabrication and assembly plant in the City of San Diego. It was recently announced that the foregoing corporation has been commissioned by the U. S. Department of Defense to manufacture the Intercontinental Ballistic Missile (Atlas). The corporation intends to construct a large plant for this purpose on the Kearney Mesa just north of the City of San Diego. The development will consist of a fabrication and assembly plant and also a research installation. This facility will be a large factor in population growth in this area in the immediate future.

It is also expected that San Diego will grow as a trade and shipping point for the Imperial Valley and portions of Arizona and Mexico due to the existing rail facilities between these points and San Diego's excellent harbor.

The present and probable future regional breakdown in industry consists of heavy, heavy-light, and light industries located in San Diego, Chula Vista, National City, and points south, and Kearney Mesa. Heavy-light industries also are to be expected in Oceanside, Carlsbad, and some other coastal towns. Light industries will probably also be established in the previously discussed areas and in Helix Irrigation District. Other areas that may attract light industry are Rio San Diego Municipal Water District, the City of Escondido, and San Marcos. Industrial development in these latter areas is expected to be limited because of the probability of restrictions aimed at minimizing the conflict between environment created by heavy industry and good residential areas.

Other portions of the investigational area are not expected to experience any appreciable industrial development.

In summary, from the discussions and data contained in the foregoing sections, it may be generally concluded that the factors of industrial, commercial and agricultural expansion which have contributed heavily to the phenomenal

population growth in San Diego County during recent times are expected to exert their expanding influence upon the population of the service area of the proposed San Diego Aqueduct for a continuing period in the future. Further, the desirable climate and location of the service area, which has probably been the most important single factor in the afore-mentioned population growth, will continue to attract retired persons and vacationers in increasing numbers.

Although the foregoing factors do not readily lend themselves to finite determinations of population increases, it is considered that the information hereinbefore developed adequately demonstrated the validity of estimating future population for the service area of the proposed San Diego Aqueduct by modified projection of the recent population trends.

Procedure for Estimating Future Population

Future population was estimated only for San Diego County and not for the portion of Riverside County included in the investigational area. It is believed that the effect of expansion of population upon the requirements for imported water in this latter area during the chosen 40-year period will be relatively insignificant as compared with the effect of agricultural expansion and attendant increased demands for irrigation water.

The general procedure utilized consisted of first estimating the rate of growth of population for the entire State of California at ten-year intervals from 1960 until year 2000, and then estimating population of San Diego County for the same intervals, expressed as percentages of the totals for the State.

During the recently completed State-wide Water Resources Investigation, a study was conducted to estimate the ultimate population of the State. In this study, consideration was given to the availability of lands suitable for urban and suburban developments, and also to the availability of lands adaptable for irrigated agriculture which would be required to produce the food and fiber

necessary to support a large population. Consideration was also given to factors of future industrial and agricultural development necessary to provide employment for a large population. On this basis, a probable ultimate population of 42,410,000 for the entire State of California was determined.

Historical population data expressed in per cent of the estimated ultimate population were plotted against time on arithmetic probability paper, and projected until the year 2000. The historical and estimated populations of the State for five and ten year intervals until the year 2000, so derived, are shown in the following tabulation. Also shown, for comparative purposes, are estimates of future population of California made for "Report on the Collection, Treatment, and Disposal of the Sewage of San Diego County, California", by the San Diego County Sewerage Survey, and estimates prepared by California Chamber of Commerce, Stanford Research Institute, and the State of California Department of Finance. It will be noted that the projections during the period common to each are in relatively close agreement with the exception of that prepared for the San Diego County Sewerage Survey which indicated lower values throughout.

Year	Department of Water Resources	Population of California			
		San Diego County Sewerage Survey	California State Chamber of Commerce	Stanford Research Institute	State of California Department of Finance
1960	15,000,000	12,800,000	14,626,000	15,629,000	15,413,000
1965	17,100,000		16,426,000	18,059,000	17,781,000
1970	19,100,000	15,700,000		20,696,000	
1975	21,200,000		20,500,000	23,565,000	
1980	23,300,000	18,750,000			
1990	27,400,000	21,875,000			
2000	31,200,000	25,000,000			
Ulti- mate	42,400,000				

The next step in the analysis was to determine the percentage of the State's future population that would reside in San Diego County. The percentage of the population of California residing in San Diego County has increased steadily in the past as evidenced by the following tabulation:

<u>Year</u>	<u>Population of California</u>	<u>Population of San Diego County</u>	<u>Population of San Diego County in per cent of California total</u>
1900	1,485,053	35,090	2.36
1910	2,377,549	61,665	2.60
1920	3,426,861	112,248	3.28
1930	5,677,251	209,659	3.69
1940	6,907,387	289,348	4.18
1950	10,586,223	556,808	5.27
1955	13,000,000	780,000	6.00

Assuming continuance of the trend of increasing percentage of the State's population residing in San Diego County indicated in the above tabulation, a percentage of 9.0 was derived for the year 2000, with a straight-line increase assumed from 1955 to 2000. This continuing increase appears reasonable in light of the foregoing discussion of "Industrial and Commercial Growth", and in consideration of the large undeveloped areas available in the County which are among the most desirable for residential development in the State.

The percentages so obtained were applied to the previously developed estimates of State population for each decade until the year 2000. The resulting estimates of future population for San Diego County are shown in the following tabulation, together with estimates prepared in connection with the San Diego County Sewerage Survey and by the State Department of Finance:

<u>Year</u>	<u>Projected population</u>		
	<u>Department of Water Resources</u>	<u>San Diego County Sewerage Survey</u>	<u>State Department of Finance</u>
1960	952,000	925,000	1,000,000
1965	1,145,000	---	1,200,000
1970	1,337,000	1,625,000	
1980	1,794,000	2,500,000	
1990	2,288,000	2,960,000	
2000	2,810,000	3,275,000	

The foregoing estimates of future population are shown graphically on Plate 5, entitled "Historical and Estimated Future Population for San Diego County".

Having estimated the rate of growth in population in the County from the present time until the year 2000, it was next necessary to distribute this population among those portions of the County considered susceptible of urban development. The location and areal extent of lands considered to have urban potential are tabulated in Table 5 and are delineated on Plate 4, as previously stated. In distributing the future population and in estimating the rates of growth thereof in the several urban areas, consideration was given to those factors affecting density and character of urban development previously discussed. In this connection, each of the areas was given individual analysis and separate projections prepared therefor.

The San Diego County Sewerage Survey found that in 1951-52 about 85 per cent of the population of the County resided in the San Diego Metropolitan Area. It was further estimated in that survey that by the year 2000, 80 per cent of the County's population would be in the San Diego Metropolitan Area. On the basis of studies conducted in connection with the current investigation, this estimate was deemed reasonable and adopted for use in this report. The remaining population of the County, varying from about 15 per cent in the year 1960 to about 20 per cent in the year 2000, was apportioned to the remaining subareas of the County, based upon evaluation of previously discussed factors influencing urban and agricultural growth and giving consideration to land use adaptability.

Set forth in the following tabulation are the estimated future populations by decades for each of the metropolitan areas and for the remaining area of the County. Also shown are historical population data for the years 1950 and 1955 in the same areas.

<u>Year</u>	<u>San Diego Metropolitan Area</u>	<u>Oceanside- Carlsbad Metropolitan Area</u>	<u>Escondido Metropolitan Area</u>	<u>Balance of San Diego County</u>	<u>Totals</u>
1950	455,700	17,260	12,500	71,348	556,808
1955	651,900	30,500	20,000	77,600	780,000
1960	809,600	34,800	27,000	80,600	952,000
1970	1,123,000	52,600	42,000	119,400	1,337,000
1980	1,507,000	70,600	52,000	164,400	1,794,000
1990	1,876,000	109,000	57,000	246,000	2,288,000
2000	2,240,000	158,000	60,000	352,000	2,810,000

Military Population

Although the present military population in San Diego County is included in the foregoing population estimates, consideration was not given therein to the probable increase in such population that would result with advent of a national emergency or war. In order to allow for such a contingency in estimates of future water requirements, consideration was given to full mobilization of Camp Pendleton and Camp Elliott. Maximum possible mobilization strength at Camp Pendleton is estimated to be 170,000 personnel, while that of Camp Elliott is estimated to be about 30,000. About 150,000 of this population would be in addition to that included in estimates previously quoted for the entire County. For purposes of estimating water requirements, Camp Elliott was assumed to be mobilized in 1960, and Camp Pendleton was assumed to be fully mobilized in 1980, with straight-line increase in personnel between 1960 and 1980.

In the event that mobilization does not occur, it is considered that utilization of lands in portions of the two military reservations for agricultural or urban uses under interim lease arrangements could result in demands for water equivalent to or greater than those estimated for military population under full mobilization conditions. Use is presently being made of portions of Camp Pendleton for agricultural purposes under such an arrangement. As

discussed in an ensuing section, there is increasing pressure for private development of lands in Camp Elliott for urban and agricultural purposes.

It should be further emphasized that with the advent of wartime conditions, estimated rates of growth of nonmilitary population presented hereinbefore would also be substantially accelerated.

Future Agricultural Growth

It has been shown that, ultimately, irrigated agriculture could occupy a substantial portion of the land area of San Diego County. Determination of the rate of growth of irrigated agricultural lands during the 40-year period from 1960 to year 2000 was a primary consideration in this investigation since the potential irrigation use in the aqueduct service area will have a major effect in ascertaining the proper size and location of future facilities for imported water of the area. The rate of growth in irrigated agricultural land is inherently dependent on many of the factors previously discussed, including location and availability of suitable undeveloped land, markets for crops produced, price of water, and the ability of responsible local agencies to finance conveyance and distribution systems.

Presented in this section is a discussion of those principal factors affecting the growth of agriculture and assumptions made in connection with determining the rate at which this growth would occur.

Principal Factors Affecting Growth of Irrigated Agriculture

In addition to the factor of ability of local agencies to finance water supply developments, there are three basic criteria requisite to the development of irrigable land. There must be a market for the crops produced; the crops produced must have a payment capacity for irrigation water equal to or greater than the selling price of the available supply; and the investment cost of acquiring

land and preparing it for irrigation must not be beyond that which can be recovered by the investors with a reasonable return on the investment. These criteria are discussed in detail in the ensuing sections.

Market Potential for Irrigated Crops. By virtue of inherent climatic conditions, the general service area of the proposed San Diego Aqueduct is suited to a relatively wide variety of field and truck crops as well as to specialization in subtropical fruits, certain vegetables, cut flowers, and nursery stock. The degree of economic advantage which has accrued to specialized crop production in this area in the past can be expected to stimulate future expansion of acreage in such crops if water is made available to climatically suited lands, providing market outlets are available. The latter of the foregoing factors is of particular importance because of the relatively large amounts of capital needed to develop specialized farm enterprises and, in the case of crops such as cut flowers and certain truck crops, the relatively high cost of marketing specialty produce on a nation-wide scale.

In terms of both acreage and net income, avocados constitute the most important crop in the general service area of the project. At present, California produces about 80 per cent of the nation's supply of this fruit, with the major portion of the State's output originating in San Diego County, which has 60 per cent of California's avocado acreage. The major portion of California's avocados are marketed through the Calavo Growers Association which has maintained an energetic sales campaign during most of its history. This has resulted in a per capita avocado consumption in California several times that of the nation as a whole. A continued aggressive national sales promotion campaign on the part of the Calavo Growers Association should result in increased national per capita consumption of avocados approaching that of California. This consideration, coupled with the present trend of growth in the nation's population, indicates

that markets can be found for increasing tonnages of avocados, with the majority of this market increase drawing upon production in San Diego County.

Second ranking in importance among crops produced in the service area of the proposed San Diego Aqueduct are lemons. This crop, of which California is the only commercial producer, has been successfully marketed in generally increasing amounts over the past 45 years. National lemon consumption may be expected to expand as population increases and, although San Diego County does not appear to have equal competitive advantage with the Santa Barbara-Ventura area, the latter area is approaching maximum use of the available lands adaptable to lemon production while in San Diego County lands suitable for lemon production are as yet not fully developed. It can be reasonably concluded, therefore, that markets will exist for increased lemon production which may occur in the San Diego Aqueduct service area if water is made available. Since the economic outlook for lemons is not as favorable as for avocados, it is to be expected that the latter will have first choice of the climatically suited lands while lemons will be planted where their tolerance of lower temperatures is a factor. Taken together, these two crops are expected to utilize virtually all of the land which is suited to citrus and subtropical fruit production.

The three highest income truck and field crops grown in the potential service area are late fall tomatoes, celery, and cut flowers. Late fall tomatoes are marketed during the winter when competition from other tomato-producing areas is limited. Until recently, most of this crop was marketed within California but increasing quantities are being shipped out of the State. This fact, coupled with the limited amount of land in other areas climatically suited to the production of late fall tomatoes, indicates that there will be an adequate market potential for any foreseeable increase in production of this crop.

Celery, which is grown primarily in the Chula Vista area, is a high income and high production cost crop which is grown primarily for the eastern

market. San Diego County's harvest season is the same as that for the Florida celery crop, and it is not considered to have any competitive advantage over the latter area. However, it would appear that the increase in demand for food indicated by national population trends will be reflected in a substantial increase in demand for celery from San Diego County.

The major cut flower producing areas in the State are located in the San Francisco Bay area, in Los Angeles County, and in the coastal area of San Diego County. It is the consensus among staff representatives of the State Department of Agriculture that the market for California's cut flowers can readily absorb a continuing expansion in production. This, coupled with an impending encroachment of urban development into present flower growing areas in Los Angeles County, indicates the strong likelihood that there will be a greater market potential for cut flowers from San Diego County in the future than at present.

Another important specialty irrigated crop which is expected to have a substantial expansion is nursery stock. At the present time, the production of this commodity is a \$100,000,000 industry in California. However, the supply is so far behind demand that leaders in the industry foresee a need for a 50 per cent expansion in California nursery stock within the next decade. About 24 per cent of the present production in terms of value of the product originates in Los Angeles County, but the increasing pressure of encroachment of urban and suburban areas upon agricultural lands in that County is tending to push the industry southward into less congested areas. Water is the controlling element in this movement into San Diego County since there is a relative abundance of suitable land. If sufficient water of the necessary quality is made available, it is expected that several thousand acres of interior valley land which experience temperature variations that preclude the growing of other high value specialty crops will be devoted to nursery stock production.

Other farm enterprises which may be expected to utilize additional quantities of water include those associated with dairy products and poultry production, miscellaneous vegetables, and fruit and field crops for local consumption or for export to the Los Angeles Metropolitan Area. The market potential for such farm produce rests on a further population expansion in southern California. Based on historical records and current trends previously discussed, it appears that population will continue to expand at a rapid rate. This will result in a continuing increase in demand for local farm produce. The increase in demand can be partially satisfied by development of irrigated agriculture upon presently dry lands in the general service area of the proposed San Diego Aqueduct.

Costs of Land Development. In estimating future development of agricultural lands, consideration was given to the relative difficulty and expense involved in development of new land for agricultural use. Agricultural land upon which aqueduct water will be used varies greatly in the several subareas with respect to surface cover, slope, and other physical characteristics which have significant bearing on irrigation development costs. Also, the nature of the crops to be grown, with regard to the investment in permanent plantings, as well as the requirement for specialized irrigation systems, have a considerable effect on land development costs and therefore upon the rapidity of their development.

Some of the irrigable land for which new water service is contemplated has potential subdivision value. There is a tendency for this consideration to be reflected in present raw land values to such an extent as to rule out commercial irrigation development, although part-time farm units or suburban residences could well be established on such land.

Excluding potential subdivision considerations, but with recognition of variation in climate and other important factors among service areas, it is

estimated that on an average basis, current selling prices for irrigable, but presently undeveloped, agricultural land in the several subareas fall within the range of \$250 to \$1,000 per acre. Variation in land prices generally reflects income potential based on the crops which may be grown on a given piece of land. With inclusion of clearing and leveling costs, expenses associated with establishing and bringing orchards into bearing in appropriate cases, and provision for irrigation systems, developed land costs ranging from \$600 per acre for field crops to \$3,500 per acre for avocados were derived.

These costs were compared with current market prices for developed lands within each of the subareas. Where costs of developing raw lands were below the market values of presently developed lands in any subarea, it was considered that agricultural growth therein would not be limited by this factor. Conversely, where such costs would exceed the selling price of developed lands of a comparable character, it was considered growth would be inhibited.

Payment Capacity for Irrigation Water. Based on the foregoing discussion, it is concluded that there is reasonable expectation that an increased supply of agricultural produce resulting from project water service could be successfully marketed, within the scope of probable quantity relationships among commodities. However, the element of economic selectivity is expected to play an important part, within the limits imposed by pertinent physical factors, in bringing about the crop pattern which would develop with the availability of project water.

Economic selectivity as reflected by the type and size of a particular commercial farm unit is primarily a function of the income which the operator expects to receive. Income expectations arise from estimated future price and income relationships including, where irrigated agricultural development of new land is involved, consideration of the availability and probable cost of a water

supply. The cost of project water for a particular service area can be estimated in advance within limits. Therefore, consideration of water cost compared with the expected share of farm income available for its payment is essential to proper application of the element of economic selectivity in projecting a future crop pattern.

Payment capacity is derived through an analytical process patterned after the "farm efficiency" or "management" studies of the University of California Extension Service. Gross crop income is determined on the basis of conservative yield estimates (reflecting productive life in the case of perennial crops and future projection based on historical annual production records in the case of annual crops), and average local prices for the ten-year period 1946-1955. Overhead, cultural, and production costs other than payment for water and managerial skill essential to successful operation of the farm enterprise, also reflecting this base period and appropriate to the crop and locality under consideration, are likewise incorporated into the analysis. The resultant residual farm income is designated as payment capacity for project water. However, prospective project water users may require a portion of this residual income for return to management in recognition of the significance of the profit motive within the framework of economic selectivity, with the balance being available to pay for project water service. Therefore, it can be concluded that payment capacities for irrigation water, as developed within the criteria set forth above, represent ceiling amounts which irrigators can pay for project water.

Based on farm price-cost relationships prevailing during the period 1946-1955 and estimated average long-term yields, following is the relationship between the existing irrigated crop pattern and payment capacities:

<u>Crop</u>	<u>Payment capacity per acre-foot of water</u>
Avocados (mature trees), late fall tomatoes, celery, cut flowers, and nursery stock	\$100 or more
Lemons, spring and early summer vegetables	\$70 to \$99
Table grapes, most deciduous fruit, and other vegetables	\$50 to \$69
Valencia oranges	\$40 to \$49
Miscellaneous fruit and vegetable crops	\$30 to \$39
Nuts and field crops	\$20 to \$29

It should be emphasized that the foregoing values for payment capacity are for water delivered to the farmer's headgate and include all direct and indirect costs attributable to the conveyance of the water supply to the land. Prices for water quoted at the main aqueduct cannot be directly compared with the foregoing values.

In estimating rates of agricultural growth, values of payment capacity for the various climatically adapted crops projected in the several subareas were compared with assumed costs of water at the aqueduct to which was added estimated costs of conveyance and distribution. In this manner, it was possible to determine the limiting effect of price of water on irrigated agricultural development.

Estimated Rate of Growth of Irrigated Agriculture

Those presently undeveloped lands in each subarea which, as a result of the land classification studies, were considered to be susceptible of irrigated agricultural development, were analyzed on the basis of influencing factors discussed under "Methods and Procedures" and in greater detail in the immediately preceding section. Particular attention was given to the costs of providing water service to these lands, the costs of preparing them for irrigation, and to payment capacity of climatically adapted crops.

As has been indicated, estimates of irrigated agricultural development were prepared for two assumed costs of water at the aqueduct, \$15 and \$40 per acre-foot. Further, estimates of probable growth were prepared for each of the considered aqueduct routes in order to reflect the influence of aqueduct location on such growth in the potential aqueduct service area.

On the basis of preliminary analysis it was concluded that there would be no apparent difference in the total demand for imported water in the potential aqueduct service area with a variation in aqueduct location. Although the growth in certain subareas would be increased or decreased by sizable percentages depending upon aqueduct location, the over-all growth was estimated to be equivalent because increases in some areas would be compensated for by decreases in others.

Accordingly, estimates of expansion of irrigated agricultural land and attendant demands for water therefor, were taken as determined for the "W" line described hereinafter in Chapter III.

On the basis of studies described hereinbefore, it was concluded that the only apparent deterrents to the rapid development of irrigated agriculture in the potential aqueduct service area will, with the availability of an adequate water supply, be the ability to pay for such water by certain climatically adapted crops and the capacity of local agencies to finance necessary conveyance and distribution systems. It was, therefore, assumed that those agricultural areas meeting these economic and financial criteria would be in production by the year 2000. By this time it was estimated that from 103,000 to 163,000 acres of additional land would be in production in southwestern Riverside and San Diego Counties, depending on the price of the water. This represents an increase of from 200 to 300 per cent over the 50,000 acres irrigated in southwestern Riverside and San Diego Counties in 1955-56.

The presently irrigated area was estimated from field reconnaissance supplemented by data appearing in Bulletin No. 2. Values determined for present

irrigated area were considered reasonable and consistent with the accuracy of other basic data available in this investigation, but were not of the accuracy which would be obtained from a detailed land use survey.

The determination of the rate of development of irrigated agriculture for the period from 1960 until the year 2000 was based generally upon the assumption that the foregoing lands would develop rapidly during the first ten years subsequent to aqueduct construction with a slower growth thereafter. Experience of water service agencies throughout California tends to support this assumption almost universally. Tables 6 and 7 summarize, by subareas, the estimated future areas of irrigated lands in the service area for ten-year intervals to the year 2000 assuming prices for water delivered at the aqueduct of \$15 and \$40 per acre-foot, respectively. The probable growth of irrigated agriculture in the potential service area of the proposed San Diego Aqueduct for the two assumptions as to price at the aqueduct is depicted graphically on Plate 6, entitled "Estimated Future Areas of Irrigated Lands in the San Diego Aqueduct Service Area", and summarized in the following tabulation:

<u>Year</u>	<u>Area in acres</u>	
	<u>Price of water \$15 per acre-foot</u>	<u>Price of water \$40 per acre-foot</u>
1960	60,600	51,200
1970	102,900	64,800
1980	157,500	96,300
1990	192,100	127,900
2000	212,600	151,000

TABLE 6

ESTIMATED FUTURE AREAS OF IRRIGATED LANDS IN THE
SERVICE AREA OF THE PROPOSED SAN DIEGO AQUEDUCT

(Assuming a price for water of \$15 per
acre-foot delivered at the aqueduct)

Subarea	Areas in acres				
	Year	Year	Year	Year	Year
	1960	1970	1980	1990	2000
<u>San Diego County</u>					
San Diego Metropolitan Area	10,000	7,300	5,500	3,600	1,600
Oceanside-Carlsbad					
Metropolitan Area	6,000	8,500	12,000	14,000	15,000
Escondido Metropolitan Area	5,000	6,000	7,600	9,000	9,600
Santa Fe-San Dieguito Area	3,500	4,500	7,000	8,000	9,400
Bueno Colorado Municipal					
Water District	8,000	11,000	15,000	20,000	23,000
Fallbrook	6,500	7,000	7,500	6,500	6,200
Poway Municipal Water District	1,000	1,900	3,500	4,500	5,000
Rainbow Municipal Water District	3,000	4,300	7,600	11,000	13,000
Valley Center Municipal Water					
District	1,800	5,000	10,000	16,000	18,000
Ramona Municipal Water District	600	1,200	2,500	3,800	4,700
Rancho El Cajon	500	1,000	1,400	1,600	1,800
Pauma Valley	2,500	3,000	4,000	5,000	5,500
North of Santa Fe	100	500	800	1,400	2,500
South of Lake Hodges	1,000	1,500	2,600	3,800	5,600
East of Del Mar	1,400	2,500	4,000	5,800	7,000
Lower Pauma Valley	1,500	1,700	2,800	3,500	4,500
El Capitan	500	900	1,300	1,600	1,700
Rincon	1,100	1,700	2,800	3,600	4,000
San Vicente	800	1,400	2,500	3,100	3,600
Agua Tibia	0	0	200	500	700
Camp Elliott	0	0	0	0	0
Camp Pendleton	1,000	0	0	0	0
Subtotals, San Diego County	55,800	70,900	100,600	126,300	142,400
<u>Southwestern Riverside County</u>					
Temecula	0	0	500	1,800	2,800
Vail	1,800	3,000	7,400	8,000	8,400
Murrieta	1,000	2,000	9,000	12,000	14,000
Winchester South	2,000	27,000	40,000	44,000	45,000
Subtotals, Southwestern					
Riverside County	4,800	32,000	56,900	65,800	70,200
GRAND TOTALS	60,600	102,900	157,500	192,100	212,600

TABLE 7

ESTIMATED FUTURE AREAS OF IRRIGATED LANDS IN THE
SERVICE AREA OF THE PROPOSED SAN DIEGO AQUEDUCT(Assuming a price for water of \$40 per
acre-foot delivered at the aqueduct)

Subarea	Areas in acres				
	Year	Year	Year	Year	Year
	1960	1970	1980	1990	2000
<u>San Diego County</u>					
San Diego Metropolitan Area	8,000	4,600	2,800	1,800	800
Oceanside-Carlsbad					
Metropolitan Area	5,000	7,000	9,000	11,000	12,000
Escondido Metropolitan Area	4,500	5,000	5,500	6,500	7,000
Santa Fe-San Dieguito Area	3,000	3,500	5,000	6,500	7,500
Bueno Colorado Municipal					
Water District	7,000	10,000	13,000	16,000	19,000
Fallbrook	6,000	6,500	7,000	6,000	5,000
Poway Municipal Water District	800	1,500	2,200	2,800	3,500
Rainbow Municipal Water District	2,100	4,500	7,000	8,500	9,600
Valley Center Municipal Water					
District	1,000	3,300	6,800	11,000	13,000
Ramona Municipal Water District	600	700	1,000	1,800	3,200
Rancho El Cajon	400	700	900	1,100	1,400
Pauma Valley	1,800	2,200	2,700	3,000	3,300
North of Santa Fe	100	400	600	1,100	2,000
South of Lake Hodges	500	900	1,500	3,000	4,000
East of Del Mar	1,400	2,000	3,500	4,500	4,500
Lower Pauma Valley	1,500	1,500	2,000	3,000	3,500
El Capitan	500	600	700	1,000	1,300
Rincon	1,000	1,300	1,500	2,200	2,600
San Vicente	200	700	1,400	1,900	2,400
Agua Tibia	0	0	0	400	600
Camp Elliott	0	0	0	0	0
Camp Pendleton	1,000	0	0	0	0
Subtotals, San Diego County	46,400	56,900	74,100	93,100	106,200
<u>Southwestern Riverside County</u>					
Temecula	0	0	200	1,200	1,800
Vail	1,800	1,800	3,200	3,600	4,000
Murrieta	1,000	1,400	5,800	9,000	10,000
Winchester South	2,000	4,700	13,000	21,000	29,000
Subtotals, Southwestern					
Riverside County	4,800	7,900	22,200	34,800	44,800
GRAND TOTALS	51,200	64,800	96,300	127,900	151,000

Future Demands for Water

The future requirements for urban and agricultural water in the service area of the proposed San Diego Aqueduct were computed as the product of unit values of water use and projected population and irrigated area, respectively, as previously developed. The demands for additional imported water were obtained by deducting the safe yield of existing water supply facilities from the computed water requirements. After arriving at estimates of future demands for additional imported water on the two bases of price of such water, a future water demand was adopted for use in determining the proper capacity for the proposed San Diego Aqueduct.

Future Water Requirements

The foregoing sections have presented a description of the development of estimated future growth of irrigated area and population to the year 2000 for the various subdivisions of the service area of the San Diego Aqueduct. Presented in Tables 8 and 9, for each of the considered subareas, are the estimated areas of irrigated lands, appropriate units of water use, and derived agricultural water requirements for the year 2000, for prices of water delivered at the aqueduct of \$15 and \$40 per acre-foot, respectively. Presented in Table 10 for each subarea considered to have an urban potential, are estimates of the population therein for the year 2000, the appropriate value of per capita water consumption, and the derived urban water requirement in the year 2000.

Water requirements within Camp Pendleton and Camp Elliott military reservations posed a particular problem because of the uncertainty with regard to future use of lands therein. As previously stated, special provision was made for military population assuming full mobilization conditions at these Camps and computations of future urban water demands presented in this chapter

TABLE 8

ESTIMATED FUTURE WATER REQUIREMENTS OF
IRRIGATED AGRICULTURE IN SERVICE AREA OF
PROPOSED SAN DIEGO AQUEDUCT FOR THE YEAR 2000

(Assuming a price for water of \$15 per
acre-foot delivered at the aqueduct)

Subarea	: Subtropical		: Truck and		: Total annual
	: orchards		: field crops		
	: Net	: Units of:	: Net	: Units of:	
	: irrigated:	: water	: irrigated:	: water	
	: area, in	: use, in	: area, in	: use, in	: requirement,
	: acres	: feet	: acres	: feet	: in acre-feet
<hr/>					
<u>San Diego County</u>					
San Diego Metropolitan Area	800	1.9	800	2.0	3,120
Oceanside-Carlsbad Metro-					
politan Area	10,000	1.5	5,000	1.8	24,000
Escondido Metropolitan Area	5,800	2.5	3,800	2.5	24,000
Santa Fe-San Dieguito Area	7,500	1.7	1,900	3.0	18,700
Bueno Colorado Municipal Water					
District	14,000	1.5	9,000	1.5	34,500
Fallbrook	5,000	2.0	1,200	1.9	12,280
Poway Municipal Water District	3,500	1.5	1,500	1.5	7,500
Rainbow Municipal Water District	10,000	2.5	3,000	2.5	32,500
Valley Center Municipal					
Water District	13,500	2.0	4,500	2.0	36,000
Ramona Municipal Water District	3,600	2.3	1,100	2.0	10,500
Rancho El Cajon	2,000	2.3	0	0	4,600
Pauma Valley	4,800	2.0	0	0	9,600
North of Santa Fe	2,500	2.1	0	0	5,250
South of Lake Hodges	4,200	2.3	1,400	2.4	13,020
East of Del Mar	6,000	1.5	1,000	1.5	10,500
Lower Pauma Valley	4,000	1.5	500	2.0	7,000
El Capitan	700	2.3	1,000	2.3	3,910
Rincon	3,000	2.2	1,000	2.3	8,900
San Vicente	2,600	2.3	1,000	2.3	8,280
Agua Tibia	400	2.3	300	2.0	1,520
Camp Elliott	0	0	0	0	0
Camp Pendleton	0	0	0	0	0
	<hr/>		<hr/>		<hr/>
Subtotals	103,900		38,000		275,680
<hr/>					
<u>Southwestern Riverside County</u>					
Temecula	0	0	2,800	1.5	4,200
Vail	1,400	2.0	7,000	2.0	16,800
Murrieta	1,000	2.0	13,000	2.0	27,000
Winchester South	0	0	45,000	2.0	90,000
	<hr/>		<hr/>		<hr/>
Subtotals	2,400		67,800		138,000
<hr/>					
GRAND TOTALS	106,300		105,800		413,680

ESTIMATED FUTURE WATER REQUIREMENTS OF
IRRIGATED AGRICULTURE IN SERVICE AREA OF
PROPOSED SAN DIEGO AQUEDUCT FOR THE YEAR 2000

(Assuming a price for water of \$40 per
acre-foot delivered at the aqueduct)

Subarea	: Subtropical :		: Truck and :		:Total annual : water : requirement, : in acre-feet
	: orchards :		: field crops :		
	: Net :	:Units of:	: Net :	:Units of:	
	: irrigated: water : area, in : use, in : acres :	: irrigated: water : area, in : use, in : acres : feet :			
<hr/>					
<u>San Diego County</u>					
San Diego Metropolitan Area	800	1.9	0	0	1,520
Oceanside-Carlsbad Metro- politan Area	8,500	1.5	3,500	1.8	19,050
Escondido Metropolitan Area	5,800	2.5	1,200	2.5	17,500
Santa Fe-San Dieguito Area	7,500	1.7	0	0	12,750
Bueno Colorado Municipal Water District	14,000	1.5	5,000	1.5	28,500
Fallbrook	5,000	2.0	0	0	10,000
Poway Municipal Water District	3,500	1.5	0	0	5,250
Rainbow Municipal Water District	9,600	2.5	0	0	24,000
Valley Center Municipal Water District	13,000	2.0	0	0	26,000
Ramona Municipal Water District	2,400	2.3	800	2.0	7,120
Rancho El Cajon	1,400	2.3	0	0	3,220
Pauma Valley	4,500	2.0	0	0	9,000
North of Santa Fe	2,000	2.1	0	0	4,200
South of Lake Hodges	4,000	2.3	0	0	9,200
East of Del Mar	4,500	1.5	0	0	6,750
Lower Pauma Valley	3,500	1.5	0	0	5,250
El Capitan	700	2.3	600	2.3	2,990
Rincon	2,600	2.2	0	0	5,720
San Vicente	2,400	2.3	0	0	5,520
Agua Tibia	400	2.3	200	2.0	1,320
Camp Elliott	0	0	0	0	0
Camp Pendleton	0	0	0	0	0
	<hr/>		<hr/>		<hr/>
Subtotals	96,100		11,300		204,860
<hr/>					
<u>Southwestern Riverside County</u>					
Temecula	0	0	1,800	1.5	2,700
Vail	1,400	2.0	2,600	2.0	8,000
Murrieta	1,000	2.0	9,000	2.0	20,000
Winchester South	0	0	29,000	2.0	58,000
	<hr/>		<hr/>		<hr/>
Subtotals	2,400		42,400		88,700
<hr/>					
GRAND TOTALS	98,500		53,700		293,560

TABLE 10

ESTIMATED ANNUAL URBAN WATER REQUIREMENTS
IN THE SERVICE AREA OF PROPOSED SAN DIEGO
AQUEDUCT FOR THE YEAR 2000

Subarea	:	:	Estimated :	Estimated
	:	Estimated :	units of :	urban
	:	population:	water use, :	water
	:	in year :	acre-feet :	requirements
	:	2000 :	per capita:	acre-feet
	:	:	per year :	per year
San Diego Metropolitan Area	2,240,000	0.220		492,800
Oceanside-Carlsbad Metropolitan Area	158,000	0.224		35,400
Escondido Metropolitan Area	60,000	0.224		13,400
Santa Fe-San Dieguito Area	50,000	0.224		11,200
Bueno Colorado Municipal Water District	60,000	0.224		13,440
Fallbrook	30,000	0.224		6,720
Poway Municipal Water District	30,000	0.224		6,720
Rainbow Municipal Water District	20,000	0.224		4,480
Valley Center Municipal Water District	30,000	0.224		6,720
Ramona Municipal Water District	10,000	0.224		2,240
Rancho El Cajon	5,000	0.224		1,120
East of Del Mar	50,000	0.224		11,200
El Capitan	4,000	0.224		900
San Vicente	5,000	0.224		1,120
Camp Elliott	30,000	0.101		3,030
Camp Pendleton	170,000	0.101		17,170

reflect the water uses of such population. As also stated, it is believed that the water demands so developed would provide for irrigation of suitable lands in Camp Pendleton should the United States Government lease them or sell them outright.

Camp Elliott is located adjacent to the heavily developed urban areas of the San Diego Metropolitan Area, and contains large acreages of lands highly desirable for urban or agricultural development. Should a large part of these lands be released to private development, the water requirements for a Camp population under full mobilization would not be adequate to meet urban or agricultural water requirements on such lands. Therefore, it is hereinafter assumed that the Camp Elliott area would have an additional annual water requirement in the year 2000 of 7,000 acre-feet, assuming water sold at the aqueduct for \$15 per acre-foot, and 6,000 acre-feet, assuming a delivery price of \$40 per acre-foot. The estimated irrigable area in Camp Elliott is about 17,000 acres, which would require about 25,000 acre-feet per year if developed into irrigated agriculture. The amount of 3,000 acre-feet per year hereinafter estimated for the use by the Camp population under full mobilization conditions, and the foregoing additional amounts make a total of 9,000 to 10,000 acre-feet which is sufficient water to irrigate about 40 per cent of the foregoing irrigable area.

The estimated growth in total water requirements in the potential aqueduct service area for both assumptions of price of water are shown graphically on Plate 7, entitled "Estimated Future Water Requirements of the San Diego Aqueduct Service Area", are summarized in the following tabulation, and are shown for the subareas by decades in Tables 11 and 12 for the two price assumptions:

Year	Annual water requirement, in acre-feet	
	Water at \$15 per acre-foot	Water at \$40 per acre-foot
1960	256,300	233,300
1970	446,800	359,700
1980	677,100	549,400
1990	887,500	751,000
2000	1,053,900	932,900

Safe Yield of Existing Water Supply Facilities

The current drought period in San Diego County which has continued for 13 years, coupled with the recent unprecedented increases in water demands in the area, has necessitated overdraft of surface storage reserves to the extent that the nominal safe yields of these facilities cannot presently be realized and will not be realized until substantial quantities of surface runoff occur. However, for the purposes of this report, the full safe yields of the local surface and underground water supplies were assumed to be available during the chosen 40-year period.

The aggregate safe annual yield of local water supply facilities in the potential aqueduct service area was estimated to be about 124,000 acre-feet. Of this amount about 58,000 acre-feet per annum represents the yield of presently developed ground water storage capacity, and about 66,000 acre-feet per annum is the nominal safe annual yield of surface storage developments. These estimates were primarily obtained from Bulletin No. 2 and other prior publications of the State Water Resources Board and Division of Water Resources.

Should subsequent hydrologic conditions make it impossible to realize the assumed safe yields over the long-term period, demands for imported water will develop more rapidly than indicated in the following estimates. Conversely, should additional conservation works be constructed in the chosen period, estimated demands for imported water would be delayed. However, it should be noted that in Bulletin No. 3 of the State Water Resources Board, it was estimated

that about 59,000 acre-feet annually represents the maximum practicable additional local yield that could be developed.

In order to obtain estimates of safe yield for each of the subdivisions of the investigational area, it was necessary to prorate estimates of safe yield for larger areas as determined in the foregoing publications. The safe yields of local water supplies for each subarea so estimated are shown in Tables 11 and 12, along with other data.

It will be noted in Tables 11 and 12 that the safe yields of local water supplies represent a rapidly decreasing percentage of the estimated future water requirements of the investigational area. For this reason the periods of relatively high or low local surface runoff in the area are expected to have a rapidly decreasing effect upon demands for imported water in the individual years.

In addition to supplies available from local conservation facilities, as much as 141,500 acre-feet of Colorado River water per year could be conveyed in the two barrels of the existing San Diego Aqueduct for use by members of the San Diego County Water Authority. It was herein assumed that the existing and proposed aqueducts would be jointly operated for the mutual benefit of the entire service area.

Demands for Imported Water

The estimated safe annual yields of local water supplies available to each subarea were deducted from estimates of future water requirements therefor to obtain total demands for imported water. These demands for each subarea in the potential aqueduct service area for assumed prices of water at the aqueduct of \$15 and \$40 per acre-foot are contained in Tables 13 and 14, respectively.

TABLE 11

ESTIMATED ANNUAL SAFE YIELDS OF LOCAL WATER
SUPPLIES AND ANNUAL WATER REQUIREMENTS IN THE
SERVICE AREA OF THE PROPOSED SAN DIEGO AQUEDUCT

(Assuming a price for water of \$15 per
acre-foot delivered at the aqueduct)

Subarea	Annual water requirements, in acre-feet					
	Annual : safe : yield, : in : acre- : feet :					
	Year	Year	Year	Year	Year	Year
	1960	1970	1980	1990	2000	
<u>San Diego County</u>						
San Diego Metropolitan Area	59,800	141,800	209,800	294,800	394,800	495,900
Oceanside-Carlsbad Metropolitan Area	7,200	16,400	25,200	35,200	48,200	59,400
Escondido Metropolitan Area	9,000	12,800	17,800	25,000	33,000	37,400
Santa Fe-San Dieguito Area	5,600	8,400	13,800	19,600	26,600	29,900
Bueno Colorado Municipal Water District	9,000	13,000	21,000	30,000	40,000	47,900
Fallbrook	2,000	10,500	12,000	15,000	17,000	19,000
Poway Municipal Water District	400	2,400	4,800	8,200	11,400	14,200
Rainbow Municipal Water District	1,200	5,600	11,200	21,200	30,200	37,000
Valley Center Municipal Water District	800	3,600	11,800	23,800	34,800	42,700
Ramona Municipal Water District	1,000	1,000	3,300	6,600	10,200	12,700
Rancho El Cajon	400	1,700	2,700	3,900	4,700	5,700
Pauma Valley	2,000	4,200	6,100	8,000	9,200	9,600
North of Santa Fe	100	400	1,200	1,700	2,900	5,200
South of Lake Hodges	300	2,100	3,500	5,900	8,700	13,000
East of Del Mar	3,000	2,000	5,600	11,800	16,000	21,700
Lower Pauma Valley	1,000	400	1,400	4,100	6,000	7,000
El Capitan	500	500	1,200	2,100	3,500	4,800
Rincon	1,000	1,200	3,700	6,100	8,000	8,900
San Vicente	400	1,600	3,600	6,200	7,900	9,400
Agua Tibia	0	0	0	500	1,100	1,500
Camp Elliott*	0	3,400	5,000	7,000	9,000	10,000
Camp Pendleton	6,000	10,500	14,500	19,000	19,000	17,200
Subtotals, San Diego County	110,700	243,500	379,200	555,700	742,200	910,100

ESTIMATED ANNUAL SAFE YIELDS OF LOCAL WATER
SUPPLIES AND ANNUAL WATER REQUIREMENTS IN THE
SERVICE AREA OF THE PROPOSED SAN DIEGO AQUEDUCT
(continued)

(Assuming a price for water of \$15 per
acre-foot delivered at the aqueduct)

Subarea	: Annual :					
	: safe :	Annual water requirements,				
	: yield, :	in acre-feet				
	: in :	:	:	:	:	:
	: acre- :	Year :	Year :	Year :	Year :	Year
	: feet :	1960 :	1970 :	1980 :	1990 :	2000
<u>Southwestern Riverside County</u>						
Temecula	0	0	0	800	2,700	4,200
Vail	3,800	3,800	5,800	14,800	15,800	16,800
Murrieta	5,800	5,000	7,800	21,800	28,800	32,800
Winchester South	<u>4,000</u>	<u>4,000</u>	<u>54,000</u>	<u>84,000</u>	<u>88,000</u>	<u>90,000</u>
Subtotals, South- western Riverside County	13,600	12,800	67,600	121,400	135,300	143,800
GRAND TOTALS	124,300	256,300	446,800	677,100	877,500	1,053,900

*Includes allowance for agricultural water requirements of up to 7,000 acre-feet per year in year 2000.

TABLE 12

ESTIMATED ANNUAL SAFE YIELDS OF LOCAL WATER
SUPPLIES AND ANNUAL WATER REQUIREMENTS IN THE
SERVICE AREA OF THE PROPOSED SAN DIEGO AQUEDUCT

(Assuming a price for water of \$40 per
acre-foot delivered at the aqueduct)

Subarea	: Annual	:	Annual water requirements,				
	: safe	:	in acre-feet				
	: yield,	:					
	: in	:	:	:	:	:	
	: acre-	: Year	: Year	: Year	: Year	: Year	
	: feet	: 1960	: 1970	: 1980	: 1990	: 2000	
<hr/>							
San Diego County							
San Diego Metropolitan Area	59,800	133,800	199,800	289,800	389,800	494,300	
Oceanside-Carlsbad Metropolitan Area	7,200	14,800	22,200	30,200	43,200	54,500	
Escondido Metropolitan Area	9,000	11,900	15,600	21,000	27,000	30,900	
Santa Fe-San Dieguito Area	5,600	7,600	11,800	17,600	22,600	24,000	
Bueno Colorado Municipal Water District	9,000	12,200	18,500	26,000	34,000	41,900	
Fallbrook	2,000	9,500	10,800	13,000	15,000	16,700	
Poway Municipal Water District	400	2,000	3,900	6,900	9,900	12,000	
Rainbow Municipal Water District	1,200	4,400	9,000	16,200	24,200	28,500	
Valley Center Municipal Water District	800	2,600	8,800	17,800	26,800	32,700	
Ramona Municipal Water District	1,000	1,000	1,200	3,200	5,300	9,400	
Rancho El Cajon	400	1,600	2,400	3,000	3,700	4,300	
Pauma Valley	2,000	3,700	5,500	7,300	8,600	9,200	
North of Santa Fe	100	300	800	1,300	2,300	4,100	
South of Lake Hodges	300	800	2,000	3,400	7,000	9,300	
East of Del Mar	3,000	1,800	4,800	11,100	15,000	18,000	
Lower Pauma Valley	1,000	300	900	2,300	4,600	5,500	
El Capitan	500	400	1,000	1,500	2,800	3,900	
Rincon	1,000	600	1,700	3,200	4,900	5,800	
San Vicente	400	700	1,700	3,600	5,100	6,600	
Agua Tibia	0	0	0	0	800	1,300	
Camp Elliott*	0	3,000	4,500	6,000	8,000	9,000	
Camp Pendleton	6,000	9,000	13,000	17,000	17,000	17,200	
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Subtotals, San Diego County	110,700	222,000	339,900	501,400	677,600	839,100	

ESTIMATED ANNUAL SAFE YIELDS OF LOCAL WATER
SUPPLIES AND ANNUAL WATER REQUIREMENTS IN THE
SERVICE AREA OF THE PROPOSED SAN DIEGO AQUEDUCT
(continued)

(Assuming a price for water of \$40 per
acre-foot delivered at the aqueduct)

Subarea	Annual water requirements, in acre-feet					
	Annual	safe	yield,			
	in	acre-	Year	Year	Year	Year
	feet	feet	1960	1970	1980	1990
Southwestern Riverside County						
Tamecula	0	0	0	300	1,800	2,700
Vail	3,800	3,800	3,800	7,300	7,800	8,300
Murrieta	5,800	3,500	6,600	15,400	21,800	25,800
Winchester South	4,000	4,000	9,400	25,000	42,000	57,000
Subtotals, Southwestern Riverside County	13,600	11,300	19,800	48,000	73,400	93,800
GRAND TOTALS	124,300	235,300	359,700	549,400	751,000	932,900

*Includes allowance for agricultural water requirements of up to 6,000 acre-feet per year in year 2000.

TABLE 13

ESTIMATED FUTURE DEMANDS FOR IMPORTED WATER IN
THE SERVICE AREA OF THE PROPOSED SAN DIEGO AQUEDUCT

(Assuming a price for water of \$15 per
acre-foot delivered at the aqueduct)

Subarea	Annual demand in acre-feet				
	Year	Year	Year	Year	Year
	1960	1970	1980	1990	2000
<u>San Diego County</u>					
San Diego Metropolitan Area	82,000	150,000	235,000	335,000	436,100
Oceanside-Carlsbad					
Metropolitan Area	9,200	18,000	28,000	41,000	52,200
Escondido Metropolitan Area	3,800	8,800	16,000	24,000	28,400
Santa Fe-San Dieguito Area	2,800	8,200	14,000	21,000	24,300
Bueno Colorado Municipal					
Water District	4,000	12,000	21,000	31,000	38,900
Fallbrook	8,500	10,000	13,000	15,000	17,000
Poway Municipal Water District	2,000	4,400	7,800	11,000	13,800
Rainbow Municipal Water District	4,400	10,000	20,000	29,000	35,800
Valley Center Municipal Water					
District	2,800	11,000	23,000	34,000	41,900
Ramona Municipal Water District	0	2,300	5,600	9,200	11,700
Rancho El Cajon	1,300	2,300	3,500	4,300	5,300
Pauma Valley	2,200	4,100	6,000	7,200	7,600
North of Santa Fe	300	1,100	1,600	2,800	5,100
South of Lake Hodges	1,800	3,200	5,600	8,400	12,700
East of Del Mar	0	2,600	8,800	13,000	18,700
Lower Pauma Valley	0	400	3,100	5,000	6,000
El Capitan	0	700	1,600	3,000	4,300
Rincon	200	2,700	5,100	7,000	7,900
San Vicente	1,200	3,200	5,800	7,500	9,000
Agua Tibia	0	0	500	1,100	1,500
Camp Elliott	3,400	5,000	7,000	9,000	10,000
Camp Pendleton	4,500	8,500	13,000	13,000	11,200
Subtotals, San Diego County	134,400	268,500	445,000	631,500	799,400
<u>Southwestern Riverside County</u>					
Temecula	0	0	800	2,700	4,200
Vail	0	2,000	11,000	12,000	13,000
Murrieta	0	2,000	16,000	23,000	27,000
Winchester South	0	50,000	80,000	84,000	86,000
Subtotals, Southwestern					
Riverside County	0	54,000	107,800	121,700	130,200
GRAND TOTALS	134,400	322,500	552,800	753,200	929,600

TABLE 14

ESTIMATED FUTURE DEMANDS FOR IMPORTED WATER IN
THE SERVICE AREA OF THE PROPOSED SAN DIEGO AQUEDUCT

(Assuming a price for water of \$40 per
acre-foot delivered at the aqueduct)

Subarea	Annual demand in acre-feet				
	Year	Year	Year	Year	Year
	1960	1970	1980	1990	2000
<u>San Diego County</u>					
San Diego Metropolitan Area	74,000	140,000	230,000	330,000	434,500
Oceanside-Carlsbad					
Metropolitan Area	7,600	15,000	23,000	36,000	47,300
Escondido Metropolitan Area	2,900	6,600	12,000	18,000	21,900
Santa Fe-San Dieguito Area	2,000	6,200	12,000	17,000	18,400
Bueno Colorado Municipal					
Water District	3,200	9,500	17,000	25,000	32,900
Fallbrook	7,500	8,800	11,000	13,000	14,700
Poway Municipal Water District	1,600	3,500	6,500	9,500	11,600
Rainbow Municipal Water District	3,200	7,800	15,000	23,000	27,300
Valley Center Municipal Water					
District	1,800	8,000	17,000	26,000	31,900
Ramona Municipal Water District	0	200	2,200	4,300	8,400
Rancho El Cajon	1,200	2,000	2,600	3,300	3,900
Pauma Valley	1,700	3,500	5,300	6,600	7,200
North of Santa Fe	200	700	1,200	2,200	4,000
South of Lake Hodges	500	1,700	3,100	6,700	9,000
East of Del Mar	0	1,800	8,100	12,000	15,000
Lower Pauma Valley	0	0	1,300	3,600	4,500
El Capitan	0	500	1,000	2,300	3,400
Rincon	0	700	2,200	3,900	4,800
San Vicente	300	1,300	3,200	4,700	6,200
Agua Tibia	0	0	0	800	1,300
Camp Elliott	3,000	4,500	6,000	8,000	9,000
Camp Pendleton	3,000	7,000	11,000	11,000	11,200
Subtotals, San Diego County	113,700	229,300	390,700	566,900	728,400
<u>Southwestern Riverside County</u>					
Temecula	0	0	300	1,800	2,700
Vail	0	0	3,500	4,000	4,500
Murrieta	0	800	9,600	16,000	20,000
Winchester South	0	5,400	21,000	38,000	53,000
Subtotals, Southwestern					
Riverside County	0	6,200	34,400	59,800	80,200
GRAND TOTALS	113,700	235,500	425,100	626,700	808,600

Estimated annual demands for additional imported water were computed by deducting the conveyance capacity of the existing aqueduct from requirements for imported water, shown in Tables 13 and 14, and are tabulated below by decades for the entire service area:

<u>Year</u>	<u>Annual demand for additional imported water in acre-feet</u>	
	<u>Water at \$15 per acre-foot</u>	<u>Water at \$40 per acre-foot</u>
1960	0	0
1970	181,000	94,000
1980	411,300	283,600
1990	611,700	485,200
2000	788,100	667,100

Design Demand for Additional Imported Water

The inherent uncertainties relative to estimating demands for water in the potential service area of the San Diego Aqueduct necessitated employment of certain assumptions in preparing these estimates as previously described. A finite determination of the prices that will be charged for water from the aqueduct cannot be made at this time. Neither can it be predicted whether additional conservation works will be constructed in the area which as indicated would to some extent affect the demand for imported water. Further, the advent of a national emergency, or repetition of conditions prevailing during World War II in the San Diego area would greatly accelerate estimated rates of growth presented herein.

As shown in the previous section, there would be a difference in the demand for water from the proposed San Diego Aqueduct in the order of about 15 per cent, based upon the two selling prices for water delivered therefrom assumed herein for analytical purposes. It is also shown that with a lower price for water, the development of demand for additional imported water will be more rapid than with a higher price.

In order to provide a basis for selection of the proper aqueduct capacity, it was deemed reasonable to assume that the actual demand for additional imported water in the year 2000 would be approximately midway between the values derived for the two assumed selling prices therefor. The value of 724,000 acre-feet per annum in the year 2000 was therefore adopted for design purposes which amount is equivalent to a continuous flow of 1,000 second-feet.

Set forth in the following tabulation are the water demands by decades up to the year 2000 which served as the basis for the following analyses of alternative aqueduct routes to San Diego County:

<u>Year</u>	<u>Second-feet</u>	<u>Acre-feet per year</u>
1960	0	0
1970	231	167,000
1980	485	351,000
1990	743	538,000
2000	1,000	724,000

CHAPTER III. ALTERNATIVE AQUEDUCT ROUTES

Upon initiation of preliminary studies for an aqueduct to convey Feather River Project water to San Diego County, the Department of Water Resources was able to draw upon the experience of the past several years of the Division of Water Resources in its work for the State Water Resources Board on studies for The California Water Plan and upon prior investigational work conducted for the Feather River Project. In connection with these two studies, preliminary investigations, paper locations, and reconnaissance type estimates of cost were made for numerous aqueduct routes leading to San Diego County. In addition, of great value was the work done by the San Diego County Water Authority and presented in "Report on the Probable Extent of Authority Area, the Amount and Source of Additional Water Supply Required, and the System Required to Efficiently Deliver Authority Water to the Agencies Comprising that Area", dated June, 1955, together with "Report on Water Supply for Probable Future Developments in the San Diego County Water Authority", prepared by a Board of Engineers composed of Raymond A. Hill, John S. Longwell, and Carl R. Rankin, dated September 12, 1955.

During the course of the investigation, The Metropolitan Water District of Southern California initiated a study of an aqueduct from the vicinity of San Jacinto south to San Diego County. Studies of that agency were also of material assistance to the Department of Water Resources.

As stated, an initial premise in the studies of alternative aqueduct routes to San Diego County was that this aqueduct would, until Feather River Project water were made available in the South Coastal Area, be capable of conveying to the aqueduct service area presently surplus Colorado River water available at facilities of The Metropolitan Water District of Southern California near San Jacinto. From the afore-mentioned studies and from preliminary work

conducted during the current investigation, it was concluded that the aqueduct should head at some point between the westerly portal of the San Jacinto Tunnel of the Colorado River Aqueduct and Lake Mathews. Several possible routes heading southerly toward the Temecula River-Rainbow Pass area were considered worthy of investigation.

South of the Temecula River-Rainbow Pass area, it was concluded early in the investigation that four general routes, which satisfied the initial premise of conveyance of Colorado River water in the interim until Feather River Project water would be available, should be given study. These alignments are delineated on Plate 9, entitled "Alternative Aqueduct Routes", and are described as follows: (1) the Barona, or "B" line, which would follow an alignment easterly of the existing San Diego Aqueduct and at a higher elevation to a terminus in the proposed Barona Reservoir near the existing San Vicente Reservoir. This line is similar to that described in State Water Resources Board Bulletin No. 3, but would require a pump lift of about 200 feet from the hydraulic gradient of the Metropolitan Water District facilities; (2) a line parallel to the existing San Diego Aqueduct and extending south of the City of San Diego, designated the "E" line; (3) a line generally following the alignment studied by the San Diego County Water Authority and described in its aforementioned report, designated the "S" line; and (4) a line, designated the "W" line, further to the west but with a hydraulic gradient comparable to that of the "S" line.

The alignments of these four routes generally traverse most of the coastal area of San Diego County wherein demands for water are expected to develop over the next 40 years as determined in Chapter II. In consideration of the premise that the aqueduct should be capable of interim conveyance of presently surplus Colorado River water, it was concluded that the foregoing alignments generally comprise all of the feasible routes that fall within the scope of this investigation.

Intensive study was given to each of the foregoing routes to evaluate the costs and accomplishments thereof. Described in this chapter are methods and procedures utilized in comparing the routes and estimating costs therefor; a description of each route together with the results of the investigation thereof; a comparison of the costs and accomplishments of the routes; and an economic analysis of staged construction of the route selected as being superior to the others.

Methods and Procedures

Proper economic comparison of the four aqueduct routes studied, necessitated consideration of the cost not only of the aqueduct proper but also of serving and regulating water in areas of need in the potential aqueduct service area. In this manner, the over-all capital costs of delivery of water at strategic locations in the potential water service area of the aqueduct were taken into account in evaluating the merits of one route as compared with the others.

In making the economic comparison of the aqueduct routes studied, including appurtenant storage and conveyance facilities, cost estimates were carried only to the degree of refinement necessary for a proper comparison of the costs of each of the alternative routes. The costs of certain items considered to be common to each of the routes were not included. Therefore, the estimated costs presented later in this chapter for comparative purposes do not completely reflect the actual cost of construction. It should be noted that estimated costs hereinafter presented in the various comparisons of alternative aqueduct routes, as well as in the analysis of staged construction of the features of the aqueduct route hereinafter selected as being superior to other routes studied, are all of a preliminary nature. These preliminary estimates were prepared from reconnaissance layouts on U. S. Geological Survey quadrangles

supplemented by only general field examination of the routes studied and sites utilized. Unit prices were of a preliminary nature and in many cases consisted of weighted average costs from experience on similar projects.

Economic comparison of the aqueduct routes was made on the basis of these preliminary capital costs, including a 10 per cent allowance for administration and engineering and 15 per cent for contingencies. Also included was interest during one-half of the estimated construction period at 4 per cent per annum. In those instances where proper economic comparison necessitated consideration of the cost of pumping water, the present value of future annual pumping charges, assuming an interest rate of 3-1/2 per cent, was included.

A detailed cost estimate was prepared for the features hereinafter selected for initial construction. This cost estimate was prepared from detailed layouts of the features on U. S. Geological Survey quadrangles at a scale of 1 inch equals 2,000 feet and with contour intervals of 20 and 25 feet. These map layouts were supplemented by field reconnaissance of the entire line and, in the instance of certain structures, additional site topography was obtained by survey crews in the field. Unit prices of construction items were determined from recent bid data on similar projects and from data furnished by pipe and equipment manufacturers. Prices utilized are considered representative of those prevailing in the fall of 1956.

Design features of plans upon which the foregoing detailed cost estimate was based are necessarily of a preliminary nature and primarily for cost estimating purposes. More detailed investigation, which would be required in order to prepare construction plans and specifications, might result in designs differing in detail from those presented in this report. However, it is believed that such changes would not result in significant modifications in estimated costs.

It will be noted that no subsurface drilling was done at the various dam sites or along the aqueduct route with the exception of the drilling performed by The Metropolitan Water District of Southern California along a portion of the canal section.

The Department of Water Resources during this investigation retained the services of Mr. A. H. Ayers, Consultant Civil Engineer, who reviewed the adopted unit prices for excavation, backfill, and structural concrete, and advised the Department on construction methods and procedures for cost estimating purposes.

Size and Capacity of Aqueducts for Preliminary Route Comparisons

The economic comparison of the considered alternative routes was based on a size of aqueduct that would supply the probable demand for imported water in San Diego and southwestern Riverside Counties in the year 2000 hereinbefore developed in Chapter II. This resulted in a design capacity of about 1,000 second-feet for each aqueduct at its point of take-off from facilities of the Metropolitan Water District. For each alternative aqueduct location, it was assumed that this discharge would be conveyed in a single conduit extending to a chosen terminal point in San Diego County. In each case, the capacity of aqueduct was diminished as it proceeded southward in accordance with the estimated demand thereon, as developed in Chapter II. Although it was recognized that further detailed analysis would be necessary for selection of the proper initial capacity of the selected aqueduct route, it is believed that the chosen capacity provides an adequate basis for comparison of the accomplishments and costs of the four considered routes for purposes of making a selection of the proper route.

It was assumed that in the year 2000 the supply of water available to the aqueduct would be on a continuous flow basis, and, as a result, at that

time about 150,000 acre-feet of storage capacity would be required to regulate continuous flow in the existing and proposed aqueducts to monthly irrigation and urban demand schedules. The required amount of storage capacity was based upon monthly demand schedules developed in Chapter II. The assumption that the aqueduct would receive water on a continuous flow basis is considered reasonable from the standpoint of ease of operation of the system supplying water thereto and, since on the basis of preliminary examination it was considered that regulatory storage capacity could be constructed in the San Diego Aqueduct service area at substantially lesser cost than providing excess capacity for peaking purposes in the Feather River Project Aqueduct. Further, the Colorado River Aqueduct east of Lake Mathews is designed for continuous flow operation.

Several factors affected the selection of type and size of aqueduct to convey the design discharge. These factors included the location and elevation of natural control points, elevation of delivery points for aqueduct water giving consideration to pumping that would be required, and the elevation of available sites for regulatory or terminal storage.

For each of the considered routes, comparative analyses were made of economic size and hydraulic gradient giving consideration to the foregoing factors. Due consideration was also given to the required size and general location of major laterals to the various subareas described in Chapter II from each aqueduct and to the locations of regulatory storage capacity. Thus, for each of the considered aqueduct routes, it was possible to determine the proper distribution of the required regulatory storage capacity in its relationship to size of the main aqueduct and major laterals therefrom.

After preliminary study, it was concluded that adequate comparison of the accomplishments and costs of each of the routes would be obtained by assuming

Lower Otay Reservoir as a point of terminus with a terminal hydraulic grade line elevation in the aqueduct of about 550 feet.

As hereinafter described, subsequent economic analyses of terminal facilities were made to compare the advantages of Lower Otay Reservoir with an alternative terminal reservoir site located immediately upstream and herein designated Minnewawa Reservoir. It was found, however, that conclusions reached as to the relative merits of the different routes would not have been affected had the alternative Minnewawa site been taken as the terminal point in the comparative analyses.

As previously stated, it was considered that the existing San Diego Aqueduct, with a capacity of about 195 second-feet, would be operated as an integrated unit with the new aqueduct. Therefore, for each of the routes considered, the most economical plan of serving water to San Diego and southwestern Riverside Counties was developed, which, in certain instances, dictated delivery of water from the existing aqueduct to lands not now receiving water service therefrom.

Preliminary Design Criteria

Preliminary designs of aqueducts and appurtenant structures, as stated, were primarily for cost estimating purposes. Designs were developed to sufficient detail to permit preparation of a sound estimate of cost and to provide assurance of engineering feasibility. Typical designs upon which estimates of cost were based are delineated on Plates 11 through 20 and are discussed in this section.

As stated previously, cost estimates prepared during this investigation included: (a) those estimates prepared on preliminary bases for purposes of economic comparison of alternative routes, utilizing weighted unit prices and based upon designs carried only to sufficient degree of detail to establish

engineering feasibility; (b) a detailed estimate of the capital costs of facilities hereinafter selected for initial construction. The following design criteria were utilized in the preparation of both of the foregoing types of cost estimates.

As hereinafter discussed, it was decided that the area traversed by the northern reach of aqueduct generally between the point of take-off from the Colorado River Aqueduct and the Temecula River area is favorably adapted to canal construction. From the Temecula River area southward, it was found that the general topography dictated the use of pipe line for the aqueduct construction. There are presented following design criteria for both canal and pipe line sections of the aqueduct.

Canals and Canal Appurtenances

The largest single influencing factor in the design of canal sections was the limitation of allowable head loss dictated by the elevation of available regulatory storage sites and the controlling elevations of certain natural topographic features along the aqueduct routes.

All canals studied were assumed to have unreinforced concrete linings. Cross sectional requirements were determined after establishment of the limiting slope utilizing a Manning's "n" value of 0.014 with side slopes of 1.5:1 throughout. Although it is recognized that in certain areas steeper side slopes could be safely constructed, the economics of canal construction dictate employment of a uniform section insofar as possible.

In those areas, where it appeared that hydrostatic pressure would develop under canal linings, underdrains were provided. Contraction of the lining was provided for by transverse grooved joints at 12-foot intervals and longitudinal joints near the toe of each side slope filled with appropriate filler material.

Canal alignments were laid out on available U. S. Geological Survey 7-1/2 minute quadrangles at a scale of 1 inch equals 2,000 feet with contour intervals of 20 feet. In all cases, field examination of a reconnaissance nature was made to confirm or adjust alignments selected by map studies. The quadrangles were enlarged to a scale of 1 inch equals 1,000 feet and the center line of the canal was plotted thereon. Having fixed the section as described, the selected alignment was that which would achieve the minimum combined cost for excavation and embankment. For each prevailing transverse slope, an optimum depth of cut was determined. When the canal section was in level country, the optimum depth was found to be such that the water surface was approximately one foot above natural ground. With transverse slopes of 30 per cent the water surface was approximately 4.0 feet above ground surface at the cut line. These water surface elevations, therefore, would permit gravity diversion to irrigation users adjacent to the canal. Geologic examination was made to determine probable excavation conditions.

In locating the canal center line, a minimum radius of curvature of 200 feet was assumed, which value meets the requirements for minimum radius in the operation of canal lining machinery. Points of intersection for the curves were so located as to best fit the terrain, and tangents were drawn to these points of intersection. Distances were scaled between points of intersection and curve distances computed. From these data the center line stationing was carried forward.

Economic studies were made for areas of deep cut to determine the advantage of rerouting the canal around such areas particularly where rock cut would be encountered. In computing all estimates a shrinkage factor of 15 per cent was employed in embankment requirements.

Borrow in earth section was assumed to be taken directly from canal right of way. In areas of rock excavation, needed embankment would generally

necessitate procurement of borrow material from adjacent acceptable borrow areas. Typical canal sections are shown on Plate 11, entitled "Typical Canal Sections".

At the point of diversion from San Jacinto tunnel portal, the canal section of the aqueduct route, hereinafter selected as the most economical, would have headworks facilities consisting of a short tunnel intersecting the existing tunnel, a flume, a siphon, and a metering structure. These structures are described in detail in Appendix B and are illustrated on Plate 13, entitled "Diversion and Metering Structures". At the point where the foregoing canal section would terminate and the flow would enter the pipe line comprising the southern portion of the proposed aqueduct, a canal terminal structure would be provided. This structure is described in detail in Appendix B and shown on Plate 18, entitled "Canal Terminal Structure".

The canal section of the selected aqueduct route would have a modified cross section at one of the points where it would cross the existing San Diego Aqueduct and would be equipped with sand trap facilities just prior to entering the pipe line. These canal structures are shown on Plate 19, entitled "Miscellaneous Canal Structures".

Siphons. Throughout the canal alignments, crossing of existing facilities such as the existing San Diego Aqueduct and large drainage channels were accomplished by the use of siphons. The two types of siphons employed were box and circular, both of reinforced concrete construction. Box siphons were used where the maximum head was 35 feet or less and circular siphons where the maximum head was over 35 feet.

Box siphons would be of two-barreled reinforced concrete type having dimensions of 8 feet by 10 feet for each barrel. Circular siphons were single barrels having a diameter of 10 feet and would be constructed either of precast

or monolithic reinforced concrete pipe. Friction losses through siphons were determined by the Manning formula using "n" values of 0.014 for concrete box siphons, 0.0115 for precast concrete pipe, and 0.012 for monolithic concrete pipe. Inlet and outlet transitions were designed to hold head losses to a minimum. Actual energy losses in the transitions were not computed but the lengths of the transitions were selected to give angles of convergence and divergence of water surface consistent with the head losses assumed. Losses equal to one-tenth of the difference in velocity head at inlets and two-tenths of the difference at the outlets were assumed, in addition to friction losses. Typical siphon and transition sections are shown on Plate 12, entitled "Typical Siphons".

Preliminary designs of siphon structures to obtain required quantities of steel and concrete were based upon similar structures now under construction by the U. S. Bureau of Reclamation on its Putah South Canal Project. Box sections were assumed to be rigid frame structures designed to withstand a head of about 35 feet. External forces considered were a uniform vertical load, and a uniform and triangular lateral load. In addition for siphons under highways and railroads, impact loading was assumed.

Prices for monolithic and precast reinforced concrete pipe obtained from pipe manufacturers were based upon a preliminary design, assuming an allowable unit stress in reinforcing steel for internal pressure equal to 13,500 pounds per square inch, and for combined internal and external loads, 20,000 pounds per square inch. Reinforced concrete pipe was used for heads up to 100 feet. Reinforced concrete cylinder pipe was used throughout for heads above 100 feet with a minimum 12-gauge steel cylinder. Total area of steel was apportioned on the basis of 60 per cent to the cylinder and inside cage and 40 per cent to the outside cage.

Cross Drainage Structures. Cross drainage along canal alignments

would not be permitted to enter the canal. Admission of such water could cause damage to the structure, would materially increase maintenance costs since this water would carry substantial bedloads, and would offer the threat of pollution and contamination of the water supply. The type of drainage structure used for design purposes was dependent upon the estimated quantity of tributary discharge and on the grade of the canal invert at the point of crossing. In the case of larger streams, generally those with an anticipated peak discharge of 1,500 second-feet or greater, during a flood with a frequency of once in one hundred years, the flow of the canal was carried under the stream in a siphon. For anticipated discharges of 1,500 second-feet or less, either an overchute or culvert structure would be provided.

Probable drainage discharge was determined by the method derived in the report "Hydrology of Western Riverside County, California", by H. C. Troxell, U. S. Geological Survey, October, 1948.

Whenever anticipated discharge was less than 40 second-feet, an economic analysis dictated a pipe overchute. This structure would be of welded steel pipe, designed for a minimum velocity within the pipe of 15 feet per second. Flared inlet and outlet transitions were provided. Where overchutes were dictated and flows were equal to or greater than 40 second-feet, rectangular concrete structures were provided. Training dikes would be constructed to guide runoff to the inlet transition section of the overchute. Flared inlet and outlet sections were provided with a rectangular section designed for a minimum velocity of 10 feet per second.

For the larger concrete overchutes, a center pier would be provided in the canal for added support, and cross struts constructed to support side-walls of the overchute. Energy dissipators would be provided at the discharge

end of overchutes and would consist of concrete "dragon teeth" in the invert. In addition, riprap would be provided downstream from the structure to reduce erosion. In the structural design of the rectangular overchute sections, it was assumed that they would have fixed end conditions at one end and would be simply supported at the other.

Typical designs of overchutes, culverts, and irrigation crossings are shown on Plate 16, entitled "Typical Overchutes, Culverts and Irrigation Crossings".

Timber Bridges. Timber bridges were provided at all farm roads and other private road crossings, secondary county roads, and at intermediate points where large holdings would be severed by the canal. These bridges were designed for H-10 loading with a roadway width of 16 feet. The bridges were located so as to cross the canal at right angles to the center line insofar as possible. It was assumed that select Douglas fir of structural grade would be used with the following unit stresses: bending, 1,600 pounds per square inch; compression parallel to the grain, 1,200 pounds per square inch; bearing, 345 pounds per square inch; shear, 100 pounds per square inch. Typical designs of timber, farm, and private road bridges are shown on Plate 14, entitled "Typical Farm and Private Road Bridges".

Concrete Bridges. Concrete bridges were used for all state highway and most county road crossings. Where the canal alignment could not be adjusted to a right angle crossing with these roadways, skew type bridges with a minimum skew angle of 75 degrees with the canal center line were used. A minimum roadway width of 40 feet from curb to curb was assumed for all state highway bridges with 26 feet curb to curb width for all county road bridges. For computation of steel and concrete requirements, H-20S 16-44 loading, set forth in the American Association of State Highway Officials Standard Specifications for Highway Bridges, was adopted. Bridges would consist of two simple

spans supported on reinforced concrete abutments with a reinforced concrete pier located at the canal center line. Spans were of flat slab construction. Typical designs of concrete county and state highway road bridges are shown on Plate 15, entitled "Typical County and State Highway Bridges".

Checks. Check structures were provided where required to effect water delivery to adjacent lands during periods of low flow in the canal. The canal section was widened at check structures so that waterway openings of the checks were approximately that of the canal cross section. Checks were equipped with single radial gates 16 feet in width and with additional openings on either side of the gate where flow would be regulated with stop planks. Friction losses through the checks were assumed to be equal to the head loss in a comparable reach of canal section. Raising and lowering of the radial gates would be accomplished by hoist cables wound on motor operated drums located on the decks above the gates. A typical check structure is shown on Plate 17, entitled "Check Structure".

Turnouts. Turnout structures were provided to effect deliveries of water to areas along the canal alignment. The turnout structure would consist of a reinforced concrete pipe placed under the canal embankment, with its invert at the same elevation as the canal invert. At the point of turnout, the canal embankment would be slotted to accommodate a vertical concrete headwall and vertical slide gate at the inlet of the concrete pipe. A typical turnout structure is shown on Plate 19, entitled "Miscellaneous Canal Structures".

Irrigation Pipe Crossings. Existing irrigation pipe lines were carried over the canal in a single span. For purposes of cost estimates, it was assumed that those known crossings, for the most part within the boundaries of the Eastern Municipal Water District, would be 18-inch pipes. These crossings

would be similar to those of the pipe overchute previously described and shown on Plate 16, entitled "Typical Overchutes, Culverts and Irrigation Crossings".

Utility Crossings. Where the canal would cross existing utilities such as power and telephone lines, alteration of these facilities to provide proper clearance over the canal embankments would generally be required. A detailed estimate of the cost of accomplishing this at each individual crossing was not made. An estimate was made of the cost of work and materials involved in a typical crossing, and this cost was multiplied by the number of crossings involved.

Pipe Lines and Appurtenances

As hereinafter described, south of the Temecula River area and to the terminal point of the various alternative routes considered in this investigation, the aqueducts would be pipe lines flowing under pressure with sections of both steel and reinforced concrete pipe. For purposes of the estimates, reinforced concrete pipe with double rubber gasket joints was used for heads up to 100 feet and lock joint concrete cylinder pipe for heads generally up to 200 feet. Where the hydrostatic head was greater than 200 feet, it was generally assumed that welded steel pipe would be employed. Departures from these criteria were made where relatively small lengths of pipe were involved.

Preliminary design criteria for concrete pipe were those previously described under "Siphons". Friction losses were computed using a Manning's "n" of 0.0115. Exterior loading was based on Marston's formula for 90 degree bedding nonprojected, with the assumption of exterior cover of 10 feet.

Steel pipe was assumed to have an interior cement mortar lining and an exterior coating of reinforced cement mortar. It was assumed that all steel pipe would have a minimum plate thickness of 7/16 inch, which would be required

to keep pipe deflection within two per cent under cover loads of 10 feet. It was assumed that steel plate conforming to specification A-245 of the American Society for Testing Materials would be utilized in fabrication of the pipe, although it is recognized that under certain conditions of high head a high strength low alloy steel might merit consideration during final design. Estimates contained herein were not based on the use of the latter material. Friction losses for steel pipe were also based on the use of Manning's formula with a "n" of 0.0115. Typical pipe line structures and trench details are shown on Plate 20, entitled "Typical Pipe Line Structures and Trench Details".

Excavation and Backfill. Estimated quantities of trench excavation for the pipe lines were determined from the profile assuming a minimum cover of three feet. In order to minimize sharp vertical curvature and unnecessary summits in the pipe grade, cuts in common material up to 20 feet in depth were made where horizontal distances were about 300 feet or less and lesser depths and lengths of cuts were made in rock depending upon the estimated cost thereof.

A reconnaissance geologic examination was made over the several routes in order to classify materials with respect to cost of excavation.

Pipe trenches were assumed to be backfilled to original ground surface and compacted to a depth sufficient to provide 120 degree bearing on the pipe. In certain instances flooded sand backfill was assumed. Backfill for all structures along the pipe line was assumed to be compacted.

Air Release and Vacuum Valve Structures. Air release and vacuum valve structures were located at summits along the pipe line to allow air to escape when pipes are being filled and to allow the entry of air when the pipe is being drained in order to prevent collapse of the pipe under operating conditions. All air valves were a combination of air-inlet and air-release valve assemblies and of the type actuated by metal floats. Standard commercial

air-release and vacuum valve assemblies were assumed. For purposes of the estimates, it was assumed that the valve opening would be eight inches in diameter.

The structure housing the valve assembly would consist of an unreinforced concrete block at the appropriate location which would encase the main pipe line and act as a base for the concrete pipe riser. The concrete block would act as a foundation for the structure as well as giving support to the pipe walls. A precast reinforced concrete pipe would fit vertically into a groove on the concrete block and serve as a chamber for the air valve and for an entrance into the manhole in the main pipe line. A typical design of these structures is shown on Plate 20, entitled "Typical Pipe Line Structures and Trench Details".

Manhole and Blowoff Structures. Manhole and blowoff structures were located in all low points along the pipe line. These structures serve two purposes: first, to drain water from the pipe line for maintenance purposes; second, to provide an entrance into the pipe for inspection and maintenance.

The structure would consist of a reinforced concrete block at the appropriate location, which would encase the main pipe line. The concrete block would act as a foundation for the structure, as well as giving support to the pipe walls. A precast reinforced concrete pipe would be fitted vertically into a groove on the concrete block and serve as a chamber for entrance into the manhole in the main pipe line. The valves and fittings were located so that water could be drained from the pipe line without removing the manhole cover.

Turnout Structures. Turnout structures were located at points along the pipe line where water would be diverted from the aqueduct. The structure would consist of an outlet from the main line to which a valve would be attached.

The valve would be enclosed in a standpipe of appropriate dimensions which would extend to approximately two feet above natural ground level. A suitable cover would be attached to the top of the vertical standpipe.

Vent Structures. Vent structures were provided wherever the grade of the pipe line approached the hydraulic grade line therein. The structure would consist of a concrete block cast around the main line upon which vertical precast concrete pipe sections would be erected. The diameter of the standpipe would be the same size as the main line, and would extend to approximately 10 feet above the hydraulic grade line. The top of the standpipe would be covered with a grating which would allow free passage of air into and out of the pipe line.

Since the design capacity of the pipe line would decrease progressively as it extends southward, there is possibility of intermittent overflow at the vent structures under certain operating conditions. Therefore, facilities were provided for collecting this overflow and leading it away from the structure. All vent structures were enclosed with chain link fence.

Road and Highway Crossings. Where the main pipe line would cross secondary and county roads, no special provision was made in the design. It was assumed that the trench would be excavated across these roads and temporary wooden bridges provided during construction. After backfilling and compacting, temporary paving would be laid followed later by replacement of the existing pavement. Where the line would cross state highways, the pipe would be placed by cut and cover methods, or by jacking a casing under the roadway and threading the pipe through, the method used depending upon the amount of traffic involved and the type of material encountered at each crossing.

Dams and Reservoirs

Dams and reservoirs were laid out on available U. S. Geological Survey quadrangles at a scale of 1 inch equals 2,000 feet enlarged to a scale of 1 inch equals 500 feet except at certain sites where topography was obtained in the field or larger scale topography was available, as described for each site in Appendix E.

A geological reconnaissance was made of the dam sites and suitable material for embankment was located for those dams which were best suited for earth or rockfill type of construction. Selection of slopes and of type of construction was based upon reconnaissance data on the character of the earth and rockfill materials available, utilizing past experience of various agencies in the construction of fill type dams.

Estimates of cost of raising the existing concrete dams at the Lower Otag and San Vicente sites were based on the amount of additional concrete required in the cross section to maintain stability and provide the required additional height, together with provision for additional appurtenant facilities.

Detailed descriptions of each of the dam and reservoir sites and of preliminary designs of structures therefor, accompanied by detailed cost estimates, are presented in Appendix E of this report.

Tunnels

Tunnel sections utilized were of a standard 9.0-foot diameter horse-shoe design employing steel ribs and timber lagging for support when necessary and would be concrete lined throughout.

Rights of Way for Canal and Pipe Lines

Right of way costs for canal sections were of a reconnaissance nature. An attempt was made in the estimates to reflect the character of the land taken, improvements affected, and severance damages resulting from loss of access and size or impaired shape. It was assumed that an average width of 150 feet would be taken for the canal.

The present market value of the land was based on records of comparable property sales available in the affected area. For the pipe lines, it was assumed that easements would be obtained, the consideration for which was assumed to be equal to one-half of the estimated cost of the land. It was assumed that a permanent easement of 100 feet would be obtained for the pipe lines.

The costs of acquisition of lands for the various reservoir sites considered were estimated in a manner similar to that described for the canals.

Unit Prices

As has been indicated, the investigation of alternative aqueduct routes to San Diego County required preparation of estimates of cost with two degrees of refinement: (a) those estimates prepared on a preliminary basis for purposes of economic comparison of alternative routes, utilizing weighted unit prices and based upon designs carried only to sufficient degree of detail to establish engineering feasibility; (b) a detailed estimate of the capital costs of facilities hereinafter selected for initial construction.

Unit prices for the detailed cost estimate were developed from several sources. Reports of the Daily Construction Service and recent construction contracts throughout western United States were employed as a guide in selecting appropriate prices for the San Diego County area. These prices were modified where

required in order to reflect particular conditions on the job under consideration.

In general, the average of the unit prices bid by the three lowest bidders on a given item were used, with this average, as stated, adjusted for the difference in current cost index and for apparent differences in construction or fabrication conditions. For special items, such as large control valves, manufacturers' prices were obtained and estimated installation costs added thereto.

Costs of pipe for both reinforced concrete and steel were supplied by major pipe manufacturers in the southern California area after consultation with personnel of the Department of Water Resources and in some cases field reconnaissance of the alignments under consideration. To the prices furnished by these manufacturers, costs of installation were added.

Set forth in Appendix C are unit prices upon which the foregoing detailed cost estimate was based.

Storage Requirements

Economical construction and satisfactory operation of an aqueduct, such as that considered herein, require the construction of reservoir storage capacity for both regulatory and emergency purposes.

Generally, in long aqueducts, economics dictate the design and operation thereof on a continuous flow basis and the use of storage capacity to regulate this continuous flow from the aqueduct to the demand schedule of the service area. Since, in the normal process of aqueduct operation, periods of shutdown are required for maintenance and inspection, additional storage is required for these purposes. It is also considered desirable to provide a further amount of storage at strategic locations so that service can be maintained in the event of unforeseen breakdowns along the aqueduct. Storage for

these latter two purposes is designated herein as "emergency storage", as differentiated from regulatory storage required for normal aqueduct operation.

Regulatory Storage

The amount of regulatory storage capacity required for imported water in year 2000 for both the existing and proposed aqueducts was determined on the basis of data presented in Chapter II. It was assumed that reservoirs operated in conjunction with the main aqueducts would provide regulation of water deliveries to monthly demand schedules. Where required daily and weekly peaks would be satisfied by local regulatory storage facilities. From data presented in Chapter II and on Plate 8, it was found that the volume of regulatory storage capacity required would vary from about 11 per cent of the estimated total annual imported water requirement in year 2000 for the San Diego Metropolitan Area to about 26 per cent of this amount for certain of the predominantly agricultural areas. The total requirement for regulatory storage capacity was found to be about 150,000 acre-feet or about 17 per cent of the total estimated annual delivery of imported water to the service area in the year 2000.

Since it was assumed that water would be delivered to the proposed San Diego Aqueduct at San Jacinto tunnel portal on a continuous flow basis, the total required storage capacity was fixed as determined above. However, determination of the proper location and distribution of the total capacity necessitated careful economic analyses of several alternative plans. Reconnaissance investigation was made of 55 potential reservoir sites. Preliminary estimates of cost were prepared for six proposed dams and reservoirs and for conveyance facilities to provide water service to the areas of need and to connect the reservoirs with the main aqueduct, with various patterns of geographical distribution of reservoir storage.

Estimates of cost were also prepared for raising Lower Otay Dam and San Vicente Dam to the heights required to provide regulatory storage capacity required for the "S" and "W" line operation hereinafter described. The estimated costs for these dams and reservoirs for the different storage capacities required in the "E" line operation were based on the foregoing estimated costs of these two dams and reservoirs adjusted for the different heights of dams required.

On the basis of these preliminary studies, the most economical plan for operation, conveyance, and regulation of the delivered supply was selected for each of the alternative aqueduct routes.

The reservoirs selected for each of the considered alternative routes and the capacities thereof are presented hereinafter for each of the alternative routes studied. Presented in Appendix E are descriptions of each of the dam and reservoir sites, for which cost estimates were prepared, including descriptions of the construction features of dams considered at these sites, and estimates of cost therefor.

Emergency Storage

As previously mentioned, emergency storage would be required in connection with the San Diego Aqueduct to maintain continuity of supply during periods of shutdown for maintenance or because of the occurrence of natural phenomena causing interruption of operation such as earthquake, damage by flood or landslide, or other acts of God.

In determining the required amount of storage capacity, consideration was given to the requirements during a period of planned shutdown for maintenance and inspection work and also to the length of time that would probably be required to repair the Colorado River Aqueduct in the event of unpredicted interruption. In this connection, the facilities of The Metropolitan Water

District of Southern California and Los Angeles Department of Water and Power were reviewed. The Metropolitan Water District at their Lake Mathews facility maintains about two months' supply for its service area for emergency and planned interruptions in the Colorado River Aqueduct. The Los Angeles Department of Water and Power in connection with the Los Angeles Aqueduct provides sufficient storage to accommodate about a three-week shutdown period.

If allowance were made for three weeks' supply during emergency and planned shutdown, reserve storage required for the proposed San Diego Aqueduct would be in the order of 50,000 acre-feet based upon estimated water deliveries in the year 2000, with a requirement of about 29,000 acre-feet based on estimated water deliveries in the year 1980. Since the City of San Diego and many of the other agencies in the San Diego County Water Authority have, and probably will continue to have, the use of several large storage reservoirs as supplementary water supply sources, the foregoing emergency storage requirements are on the conservative side. However, it appears that emergency storage is needed to provide assurance of water deliveries to areas in the northern part of San Diego County and southwestern Riverside County where storage facilities adaptable for this purpose are limited or nonexistent.

Between San Jacinto Tunnel and San Vicente Reservoir, the only storage on the existing San Diego Aqueduct is at San Jacinto Reservoir, which has a gross capacity of about 1,800 acre-feet. This relatively small amount of storage capacity would be completely ineffective in supplying needs of the service area to the south in the event of shutdown of the Colorado River Aqueduct for more than a day or two. It is believed imperative that a substantial amount of emergency storage be provided near the upper end of the proposed new San Diego Aqueduct for the afore-stated reasons.

Investigation was made of possible dam and reservoir sites between San Jacinto Tunnel and Rainbow Pass. It was found that few sites were available

and that these generally posed construction difficulties requiring large expenditure for a relatively small amount of storage capacity or were not at a proper elevation for gravity operation. Two possibilities were given detailed consideration, the existing Vail Reservoir and the Auld Valley site located on Tualota Creek, both shown on Plate 9, entitled "Alternative Aqueduct Routes". A substantial amount of storage capacity in both the existing Vail Reservoir and the proposed Auld Valley Reservoir could be utilized with gravity operation of the canal extending from San Jacinto to the vicinity of Temecula River. It was found that, in order to connect the proposed aqueduct to the existing Vail Reservoir, it would be necessary to swing the alignment a considerable distance eastward of a more or less straight line from San Jacinto tunnel portal to Rainbow Pass whereas the Auld Valley site is located very near to such a general line. Use of Vail Lake for an emergency reservoir site would therefore necessitate construction of substantially greater aqueduct length. On the basis of preliminary cost comparisons, it was indicated that the use of the Auld Valley site would be somewhat less expensive than use of the existing Vail Reservoir and, further, utilization of Vail Reservoir would interfere with an existing water conservation facility owned and operated by a private entity. For these reasons, it was concluded that the Auld Valley Reservoir would be superior to Vail Reservoir from the standpoint of providing emergency storage for the future operation of the existing and proposed San Diego Aqueducts.

It was found that a storage capacity of about 38,000 acre-feet could be obtained by construction of Auld Valley Dam with a spillway lip elevation of 1,485 feet. It should be noted that Auld Valley Reservoir would provide emergency storage for only that portion of the service area to the south. The portion of southwestern Riverside County lying north of the reservoir site, including lands within the Eastern Municipal Water District considered for service from the aqueduct, would not benefit from emergency storage in Auld

Valley Reservoir. On the basis of a three-week emergency or planned shutdown period, it is estimated that the area that would be served from the proposed San Diego Aqueduct to the north of Auld Valley Reservoir would require about 1,400 acre-feet of emergency storage in 1980, and 1,550 acre-feet in year 2000. The Eastern Municipal Water District has under consideration construction of a dam and reservoir at the Hemet site located near Hemet. It is estimated that about 28,000 acre-feet of storage capacity could be developed at this site to a maximum water surface elevation of 1,570 feet. Storage of flows from the proposed San Diego Aqueduct in this reservoir would require pumping. Until, and unless, this reservoir were constructed, two possible relief measures could be undertaken in the event of an emergency, neither of which are considered satisfactory substitutes to the construction of reservoir storage capacity for the area.

Provision could be made for pumping of ground water into the canal to tide water users over a period of emergency shutdown, or, with check structures located in the canal, as previously described, water could be pumped out of Auld Valley Reservoir and over the check structures to the service area. Each of these plans would require investment in pumping equipment that would be idle for extensive periods and, as stated, are not considered satisfactory substitutes for reservoir storage.

Analyses of Alternative Aqueduct Routes

In accordance with the basic assumptions and premises for the investigation set forth hereinbefore, a comparison was made of the several alternative aqueduct routes to San Diego County extending southerly from facilities of the Metropolitan Water District between the west portal of San Jacinto Tunnel and Lake Mathews. As stated, the preliminary comparisons were made on the basis of conveyance of 1,000 second-feet of continuous discharge which is equivalent to

the estimated demand for additional imported water in the potential aqueduct service area in the year 2000 developed in Chapter II.

The terrain south of the Colorado River Aqueduct, between San Jacinto Tunnel and Lake Mathews, consists of a series of broad interconnected valleys extending down to the Agua Tibia and Santa Rosa Mountain Ranges. South of these mountain ranges to the vicinity of San Diego, the terrain consists of moderately high mountain ridges on the east and rolling hills interlain by limited valley areas extending westward from the mountains to the coast.

The gently sloping valley lands south of the Colorado River Aqueduct merging into the moderately rolling terrain north of the Agua Tibia and Santa Rosa Mountain Ranges is adaptable to canal construction. The more rugged terrain south of these mountain ranges is considered suitable only for pipe line construction. Passes in the divide between the drainage areas of the San Jacinto and Santa Margarita Rivers are located adjacent to Rainbow Valley and Pala Creek and have elevations of about 1,300 and 1,260 feet, respectively. In order to maintain gravity flow to San Diego County and provide water service at minimum cost to the potential aqueduct service area, it was decided that the proposed San Diego Aqueduct could traverse either of these passes with a hydraulic gradient above that of the ground surface elevation of that pass through which it would be located.

It was found that from the standpoint of cost of construction of aqueducts south of the afore-mentioned drainage divide, Rainbow Pass was superior to Pala Pass for aqueducts generally parallel to or west of the existing San Diego Aqueduct, and Pala Pass was found to be more desirable for an aqueduct at an intermediate elevation such as the Barona line.

Presented following are descriptions of each of the alternative routes studied, the appurtenant facilities for conveyance of water to strategic points in the service area, the method of operation and delivery of water for

each route, and preliminary estimates of cost for the aqueducts and appurtenant facilities. The following sections deal separately with the reach of aqueduct from the Colorado River Aqueduct to Rainbow Pass and with four alternative alignments for the reach of aqueduct between Rainbow Pass and the Otay River.

It should again be emphasized that the cost estimates upon which the economic comparisons are hereinafter based were carried to a degree of refinement sufficient only to provide a basis of comparison of the alternative aqueduct routes, and, since certain items common to each of the considered lines were omitted from the estimates, they are not to be construed as representing estimates of final construction costs.

Colorado River Aqueduct to Rainbow Pass

Analyses were made of a number of diversion points from the Colorado River Aqueduct between the west portal of San Jacinto Tunnel, with a hydraulic grade line elevation of about 1,505 feet, and Lake Mathews with a maximum water surface elevation of 1,357 feet. These points were: (1) west portal of San Jacinto Tunnel, (2) Casa Loma Siphon west of San Jacinto River, (3) west end of Casa Loma Siphon, (4) east end of Lakeview Siphon, (5) Lakeview Siphon at San Jacinto River, (6) west end of Lakeview Siphon, (7) east end of Perris Valley Siphon, and (8) Lake Mathews. Each of these diversion points required a different location for an aqueduct extending to the south.

Of the eight points of diversion given study, locations (1) and (4) above were selected for more detailed analyses. The other diversion points were eliminated from further investigation because of increased lengths of, and unfavorable terrain for, aqueduct construction therefrom, and since the progressively lower hydraulic grade line in the Colorado River Aqueduct, as it proceeds west of San Jacinto Tunnel, results in increasing the size of aqueduct to the south to meet required control elevations without pumping.

Two types of aqueduct, each having a capacity of 1,000 second-feet, were studied from the diversion point at the west portal of San Jacinto Tunnel: (1) pressure pipe, and (2) a combination of lined canal and pressure pipe. The comparative costs of these two types of conduit to a common point in the vicinity of Rainbow Pass, a distance of about 30 miles, indicated an advantage of about \$13,000,000 in favor of the combination of canal and pressure pipe type construction. Because of this large differential in cost, subsequent analyses of routes heading both at San Jacinto Tunnel and at the east end of Lakeview Siphon gave consideration to construction of a combination of lined canal and pressure pipe for the northerly section of the aqueduct where the terrain is adaptable to this type of construction.

The two general routes, heading at San Jacinto tunnel portal and east end of Lakeview Siphon, were then compared on the basis of the foregoing type of construction, extending to a common elevation of about 1,300 feet at Rainbow Pass.

The aqueduct diverting at the west portal of San Jacinto Tunnel would have an initial water surface elevation of about 1,505 feet and would follow a general southwesterly alignment across the western edge of San Jacinto Valley, passing approximately three miles east of the community of Winchester. The alignment would then continue westerly and southerly through Domenigoni, French, and Auld Valleys crossing Temecula River and continuing on to Rainbow Pass. The total length of this alignment between San Jacinto Tunnel and Rainbow Pass would be about 32 miles, of which about 22 miles would be in canal section and about 10 miles in pipe line. It should be noted that this alignment is slightly different than the alignment hereinafter adopted for the reach between San Jacinto tunnel portal and Rainbow Pass shown on Plate 9. The principal difference is that this latter adopted alignment, as hereinafter described, would have a canal section about 29.5 miles in length and a pipe line section 6 miles in

length as compared to the foregoing 22 miles of canal and 10 miles of pipe line.

The alignment of the aqueduct diverting at the east end of Lakeview Siphon, at a hydraulic grade line elevation of 1,467 feet, would be generally south along the westerly periphery of the Lakeview Mountains passing just east of the community of Romoland and across the east end of Menifee Valley to a point at the southwest end of Paloma Valley. From this point the alignment is generally due south crossing Temecula River about one mile east of the community of Temecula and continuing on to Rainbow Pass. The total length of this route would be about 28.5 miles, of which about 15.5 miles would be in canal section, and the remainder in pipe line, and is shown as a dotted line on Plate 9.

A preliminary estimate of cost was prepared for facilities to provide water service from each of the considered aqueduct alignments to lands in San Jacinto Valley. It was found that the cost and degree of service provided would be equivalent from either route. It should be noted that these cost estimates were of a very preliminary nature intended only for this economic comparison and are not comparable to estimates for similar features shown in ensuing sections of this report.

On the basis of a preliminary cost analysis of the two aqueducts, each having a capacity of 1,000 second-feet, it was found that the easterly route heading at the west portal of San Jacinto Tunnel would be about two and one half million dollars cheaper than the other route considered. Further, diversion from the west portal of San Jacinto Tunnel would permit gravity diversion of aqueduct water, for regulatory and emergency storage, into the proposed Auld Valley Reservoir, hereinafter described. By construction of the new aqueduct along this route, it would be possible to utilize about 36,000 acre-feet of active reservoir storage capacity in Auld Valley Reservoir by storing to a

water surface elevation of 1,485 feet. It would not be possible to effect a gravity diversion to this reservoir site from an aqueduct heading at the east end of the Lakeview Siphon. It should be mentioned that the Auld Valley reservoir site was found to be the only feasible storage site in the area which could be utilized for regulatory and emergency purposes.

It was therefore concluded that a general aqueduct alignment heading at the west portal of San Jacinto Tunnel, as described, is superior, and as a result, no further consideration was given to the other aqueduct alignments north of Rainbow Pass.

"B" Line

The Barona Aqueduct, as described in State Water Resources Board Bulletin No. 3 (Preliminary Version), would originate at Arrowhead Springs Afterbay with a hydraulic gradient elevation of about 1,760 feet, and would extend southerly along the eastern periphery of Upper Santa Ana Valley passing between Redlands and San Bernardino in pressure conduit. The aqueduct would enter a tunnel through the Badlands area south of San Timeteo Creek, and at its southerly portal would extend southwesterly along the San Jacinto River in pressure conduit to the western portal of the San Jacinto Tunnel. From the western portal of the San Jacinto Tunnel, the Barona Aqueduct would continue to the proposed Barona Reservoir.

The portion of the Barona Aqueduct herein considered as an alternative route to San Diego County is that portion from San Jacinto south to the proposed Barona Reservoir designated the "B" line, as is shown on Plate 9.

The "B" line was selected for study in this investigation because it would be capable of serving higher and more remote areas of San Diego County as compared with the other three aqueducts considered.

Operation of the "B" line would require a pump lift of about 200 feet in the vicinity of San Jacinto in order to serve Colorado River water in the interim until Feather River Project water becomes available, at which time pumping would no longer be required since water carried from the north in the Barona Aqueduct would reach the San Jacinto area with a hydraulic grade line elevation of about 1,700 feet. As previously discussed, the definite location of the aqueduct facilities required to bring water into the San Jacinto area from the north cannot be made at this time but must await the conclusion of studies of alternative aqueduct routes from northern California.

After preliminary investigation, it was concluded that the Barona line would not adequately serve those areas of the County which have the greatest growth potential in the near future at a cost competitive with the other routes studied. It was, therefore, not further considered in this investigation. However, as indicated in State Water Resources Board Bulletin No. 3, the Barona line as well as the "High Line" route shown on Plate 9 as "The Authorized Feather River Project Aqueduct Route to San Diego County" will be needed in the future, in addition to the existing and proposed lower aqueducts, to serve the higher and more remote lands of the County.

"E" Line

The "E" line was selected for analysis because it would facilitate interconnection with the existing San Diego Aqueduct and with existing lateral conveyance systems taking water therefrom. Further, because existing conveyance systems could be connected to both the existing and proposed aqueducts, it would be possible to operate the existing aqueduct at essentially full capacity throughout the year. Since there is only about a five second-foot reduction in capacity in the existing aqueduct between San Jacinto and San Vicente Reservoirs, service to intervening areas could be provided from the "E" line, and the

existing line, as stated, could flow at essentially full capacity. This operational procedure could not be effected with the other lines considered unless expensive interconnections to the existing aqueduct were constructed at frequent intervals along the alignment. The locations of the "E" line and of required appurtenant conveyance and storage facilities are shown on Plate 10A, entitled "Location of 'E' Line and Appurtenant Facilities".

Description of Route. The "E" line, as shown on Plate 10A, from the vicinity of Rainbow Pass parallels the existing aqueduct, which crosses Rainbow Valley and passes about one mile east of the proposed Vallecitos Dam to Rainbow Tunnel. For the purposes of this investigation, it was considered that a tunnel would be constructed generally parallel to the existing Rainbow Tunnel, although preliminary estimates indicate a pipe line bypass could be constructed at about an equivalent cost.

From the south portal of the Rainbow Tunnel, the "E" line would continue parallel to the existing aqueduct across the San Luis Rey River, passing immediately east of the City of Escondido to a point just south of Lake Hodges. In the reach north of Lake Hodges, the "E" line would deviate from the existing San Diego Aqueduct line at two points where pipe line sections approximately two miles in length would bypass the existing Lilac and Red Mountain Tunnels. In this reach, the "E" line would have a tunnel section parallel to the existing Oat Hills Tunnel about three miles west of the community of Valley Center.

About one mile south of Lake Hodges, the "E" line would swing westward from the existing alignment and continue southward to the north shore of the existing Murray Reservoir. From Murray Reservoir the line would pass generally southward through La Mesa, Lemon Grove and Spring Valley, cross the Sweetwater River just downstream from Sweetwater Dam, and pass generally southeastward to a terminus at Otay Reservoir.

Construction Problems. The "E" line throughout a substantial part of its length, because of prevailing topographical conditions, would necessarily be constructed immediately adjacent to the right of way of the existing aqueduct. This close proximity would make necessary special precautions at all times to protect the existing lines from heavy impact loads, undermining, and other possible sources of damage. Trenches would be shored in many locations and heavy pads placed over the existing line wherever heavy equipment would cross. In addition, in such locations all excavated material would be dumped away from the existing lines and, where the line is on steep side slopes, this material would require a second handling. This additional work would add to the cost of the construction, but because of its somewhat intangible nature, in many cases, it could not be adequately reflected in the preliminary cost estimates.

Between Rainbow Pass and San Luis Rey River, the "E" line would traverse very rugged and remote terrain. Considerable portions of this section of alignment are on steep cross slopes where a wide working bench would have to be excavated in hard rock. Construction of the crossing of the valley of the San Luis Rey River would be costly as was the construction of the existing barrels of the San Diego Aqueduct.

South of the San Luis Rey River and to the northern limits of the City of Escondido, the terrain is rugged with considerable outcropping of rock along the entire alignment. It is expected that site preparation and trenching will be costly throughout this reach. Some construction of access roads will be required. Since a considerable length of the trenching will be in rock, it is most likely that suitable backfill material for this reach would be imported from borrow areas near the City of Escondido. The nearest railhead for this section of the line is Escondido, where most of the heavy equipment and materials would be unloaded.

In the vicinity of Escondido and southerly past the eastern edge of Lake Hodges, thence to the proposed Carroll Reservoir, there appear to be few construction difficulties. The alignment south of Carroll Reservoir to the San Diego River would present no major problems in construction. Excavation throughout this entire area should be easily accomplished, and excavated trench material appears to be suitable for backfill.

The crossing of Mission Valley Gorge on the San Diego River would be in siphon. It is believed that in the final design, consideration should be given to crossing of this gorge by an overhead structure. In the immediate vicinity of this gorge, there appear to be considerable construction problems. The terrain is rugged and excavation would be in rock.

The alignment south of Murray Reservoir as far as La Mesa poses no appreciable problems of construction. However, pipe line construction through La Mesa, Lemon Grove, and Spring Valley would be typical of pipe line construction in southern California cities. Considerable difficulty will be experienced in laying large diameter pipe line in the streets because of the lack of space and interference with traffic. It is anticipated that considerable relocation work would be required for existing underground utility lines.

From Sweetwater Reservoir to Otay Reservoir, there should be little construction difficulty. The area is presently sparsely settled, and access roads to the zone of construction are adequate. Site preparation throughout this entire reach of the line would be at a minimum, and it appears that suitable backfill material could be obtained from trench excavation.

Operation of "E" Line. Preliminary analyses of the "E" line, as well as the other lines considered, were based on supplying needs for imported water in the potential aqueduct service area in year 2000, which would require diversion of 1,000 second-feet of continuous discharge from the source of supply.

This would be in addition to the 195 second-feet which could be conveyed by the existing aqueduct, as is presently occurring. South of Rainbow Pass, the capacity of the "E" line and the other lines considered would be about 860 second-feet. As stated it was assumed that the existing and proposed aqueducts would operate as an integrated unit.

Cost comparisons were made for numerous locations and capacities of required regulatory storage reservoirs, with resulting differences in aqueduct size and capacity for various sections. In this connection, the variation in cost of delivering water to the various components of the aqueduct service area was given consideration. As a result of these studies, it was considered that south of Rainbow Pass, storage should be provided at six reservoirs. The reservoirs, with the storage capacities required to provide the desired regulation, are tabulated following:

<u>Reservoir</u>	<u>Capacity, in acre-feet</u>	<u>Maximum water surface elevation, in feet</u>
Vallecitos	10,000	938
San Marcos	16,000	421
Carroll	8,000	714
Lower Otay	68,000	534
San Vicente	18,000	667
Murray	<u>6,000</u>	540
TOTAL	126,000	

Of the foregoing reservoirs, Vallecitos, San Marcos, and Carroll would require construction of new dams. Lower Otay and San Vicente Dams would be raised 43 feet and 17 feet, respectively, to provide additional storage capacity in the amounts indicated. Murray Reservoir is an existing facility owned by Helix Irrigation District and operated by the City of San Diego.

Storage in San Vicente Reservoir in the amount of about 20,000 acre-feet is presently being utilized by the San Diego County Water Authority for

regulation of water conveyed in the existing San Diego Aqueduct. As indicated in the foregoing tabulation, the amount of storage in this reservoir needed for coordinated operation of the facilities of the proposed aqueduct located on the "E" line would be equivalent to the amount presently utilized. As stated in ensuing sections of this chapter, different amounts of storage at this site are needed for the other alternative routes studies. Therefore, in the economic comparisons of the alternative routes presented hereinafter, the capital costs of raising San Vicente Dam to provide the needed regulatory storage are included in order to reflect the economic effect of varying degrees of use of the storage in this reservoir characteristic of each route studied.

The operational procedure and conveyance and regulatory storage facilities by which water service would be provided to the various subdivisions of the service area, described in Chapter II and shown on Plate 2, from facilities of the "E" line and existing San Diego Aqueduct are set forth in the ensuing paragraphs.

As indicated on Plate 10A, water service to Agua Tibia would be provided directly from the "E" line through a lateral 1.1 miles in length. The grade line elevation for delivery to this area would be about 1,600 feet requiring a pump lift of about 350 feet from the aqueduct grade line.

Water would be turned out for Camp Pendleton, Fallbrook, and approximately two-thirds of the Rainbow Municipal Water District near the proposed Vallecitos Reservoir. Water for Fallbrook would be conveyed directly from the "E" line through the existing Fallbrook-Oceanside Lateral, the existing Fallbrook Lateral, and a new lateral 3.6 miles in length. Water service could be provided at a grade line elevation of 800 feet by gravity.

The north two-thirds of Rainbow Municipal Water District could be served directly from the "E" line through the existing Rainbow Lateral, the existing Canonita Lateral, and through a new lateral which would also serve the

Camp Pendleton area. The proposed Vallecitos Reservoir, with a minimum operating water surface elevation of 830 feet, would provide regulation for water supplies delivered in this vicinity. Rainbow Municipal Water District could be served with water at a grade line elevation of 600 feet through these various laterals by gravity. Water service for Camp Pendleton would be provided through a new lateral 11.2 miles in length also serving a portion of Rainbow Municipal Water District. Camp Pendleton could be served at a grade line elevation of 400 feet without pumping.

Pauma Valley and Lower Pauma Valley would be served directly from the "E" line. A common lateral 2.7 miles in length would extend up Lower Pauma Valley to the vicinity of Pala, and the lateral for Pauma Valley with a length of 4.9 miles would continue from there up to the service area. A second lateral 1.7 miles in length would serve the western portion of Lower Pauma Valley. Lower Pauma Valley and Pauma Valley could be served at grade line elevations of 500 and 1,100 feet, respectively, from these laterals without pumping.

The south one-third of the Rainbow Municipal Water District, the Valley Center Municipal Water District, Rincon del Diablo Municipal Water District, and the City of Escondido, all of which now receive water from the existing San Diego Aqueduct, would, in lieu thereof, with construction of the "E" line, be served directly from the latter line. Existing laterals serving these areas would be connected to the "E" line. In order to provide for anticipated future demands in these areas, new laterals would be required for the three districts which could be served aqueduct water by gravity at elevations of 600 feet, 1,100 feet, and 1,000 feet, respectively. The City of Escondido could be served at a grade line elevation of 850 feet by gravity. The new laterals to the south one-third of the Rainbow Municipal Water District and the Valley Center Municipal Water District would be 4.2 and 0.8 miles in length, respectively.

Oceanside, Bueno Colorado Municipal Water District, Near Oceanside, Santa Fe Irrigation District, North of Santa Fe, and a portion of the demand of Carlsbad Municipal Water District would be served directly from the "E" line. A portion of the demand for the Oceanside area would be served from the existing San Diego Aqueduct through the existing Fallbrook-Oceanside Lateral and the remainder from a new lateral system, with an aggregate length of 35.0 miles, which would also serve Bueno Colorado Municipal Water District, Santa Fe Irrigation District, North of Santa Fe, Near Oceanside, and Carlsbad Municipal Water District. A portion of the Carlsbad demand would also be served through a new lateral, 4.4 miles in length, from the proposed San Marcos Reservoir, which would have a minimum operating water surface elevation of 365 feet. Oceanside, Bueno Colorado Municipal Water District, Near Oceanside, Santa Fe Irrigation District, North of Santa Fe, and Carlsbad Municipal Water District could be served at grade line elevations of 400, 900, 300, 600, 500, and 340 feet, respectively, by gravity.

San Dieguito Irrigation District and East of San Dieguito would also be served from the proposed San Marcos Reservoir. Conveyance of water to the San Dieguito Irrigation District area would be through a new lateral, branching from the Carlsbad Lateral, 4.7 miles in length, and connected to the existing line which runs from San Dieguito Reservoir. The capacity of the existing lateral is estimated to be sufficient to meet the monthly peak demands of this area in the year 2000. The area East of San Dieguito would be served through the new lateral. Delivery to these areas could be made at grade line elevations of 250 and 320 feet, respectively, by gravity.

The Rincon area would be served directly from the "E" line through a new lateral with a length of 1.7 miles. A pump lift of approximately 200 feet would be required to serve this area at a grade line elevation of 1,100 feet.

The area South of Lake Hodges could be served by gravity at a grade line elevation of 600 feet directly from the "E" line through a new lateral 4.0 miles long.

The Ramona Municipal Water District and Poway Municipal Water District areas would be served directly from the "E" line. Service to the Ramona Municipal Water District area would be through a new lateral 7.0 miles in length and would require a pump lift of approximately 700 feet to a grade line elevation of 1,500 feet. Poway Municipal Water District at present is served from the existing San Diego Aqueduct. In the future the entire supply for this area would be delivered through the foregoing new Ramona Lateral connected to existing distribution facilities. No pumping would be required to serve this area at grade line elevation of 800 feet.

The areas designated East of Del Mar, Camp Elliott, and Near Miramar would be served directly from the "E" line, with the portion of the service area of the City of San Diego in this vicinity taking water from the "E" line during low demand months and from the proposed Carroll Reservoir during peak demand months. Carroll Reservoir would have a minimum operating water surface elevation of 610 feet. Gravity service could be provided to East of Del Mar, City of San Diego, and Near Miramar at a grade line elevation of 500 feet and to Camp Elliott at a grade line elevation of 600 feet. A common lateral 4.4 miles in length would serve the Camp Elliott and Near Miramar areas and laterals 7.1 miles and 3.2 miles in length would serve the City of San Diego and East of Del Mar areas, respectively.

Service to the Rancho El Cajon, El Capitan, and San Vicente areas would be made from San Vicente Reservoir from water supplies delivered to the reservoir from the existing aqueduct. New laterals to these areas would have lengths of 3.0, 9.5, and 2.6 miles, respectively. The maximum water surface elevation in San Vicente Reservoir would be 667 feet and the minimum would be

460 feet. The hydraulic grade line elevation of the existing aqueduct at the point where it discharges into the reservoir is about 750 feet. Delivery to the foregoing areas would require the construction of laterals and pumping installations to reach grade line elevations of 1,300, 2,000, and 1,460 feet, respectively.

For the purpose of analyzing the deliveries of water from San Vicente Reservoir to Rio San Diego Municipal Water District, Helix Irrigation District, and a portion of the City of San Diego, the assumption was made that the La Mesa-Sweetwater extension; the City of San Diego's bypass line from the existing aqueduct; the lines diverting directly from San Vicente Reservoir; and the Helix-Rio San Diego bypass, all shown on Plate 2, would be used jointly by the afore-mentioned areas. It is estimated that there is sufficient capacity in these existing lines to convey to the above-noted areas the monthly peak water demands estimated for the year 2000. Water delivered through the bypass lines would require pumping to serve Rio San Diego at a grade line elevation of 850 feet, but no pumping would be required to serve Helix Irrigation District and the City of San Diego at grade line elevations of 640 feet and 540 feet, respectively, from the bypass lines. Water delivered from San Vicente through the City of San Diego's pipe lines would require pumping when the water surface in the reservoir is at a minimum, to serve the above-mentioned areas.

A portion of the water service for the City of San Diego and South Bay Irrigation District and National City would be provided directly from the "E" line by gravity. Part of the service to the City of San Diego would be provided with water from the "E" line delivered to Murray Reservoir.

During months of peak demand, water service for portions of the City of San Diego and South Bay Irrigation District and National City would be provided from Lower Otay Reservoir requiring a maximum pump lift of about 240 feet to deliver water to these agencies at grade line elevations of 540 and 400 feet,

respectively. Lower Otay Reservoir after enlargement would have a maximum water surface elevation of 534 feet and a minimum water surface elevation of 370 feet. Delivery to these areas from Lower Otay Reservoir during such times would be made by backflow through the "E" line, whereby water could be pumped from the reservoir back into the aqueduct.

Otay Municipal Water District and Imperial would be served water from Lower Otay Reservoir. A maximum pumping lift of 230 feet would be required to serve Otay Municipal Water District at a grade line elevation of 570 feet. No pumping would be required to supply Imperial at a grade line elevation of 300 feet. Service to Imperial would be through a lateral 8.6 miles in length and service to Otay Municipal Water District would be provided from a branch line from the Imperial Lateral 0.8 mile in length.

Estimated Cost of "E" Line and Appurtenant Facilities. A preliminary estimate of cost was prepared for the "E" line, together with the cost of those conveyance laterals and regulatory storage facilities needed to supply the demand for imported water in the service area in year 2000. This estimate of cost is presented in Table 15.

TABLE 15

ESTIMATED COST OF "E" LINE TO MEET DEMAND FOR IMPORTED WATER TO
SAN DIEGO COUNTY IN YEAR 2000, INCLUDING REGULATORY RESERVOIRS
AND MAJOR LATERALS AND APPURTENANT FACILITIES

Item	: Unit	: Quantity	: Unit price	: Cost
Aqueduct Cost				
<u>Rainbow Pass to San Marcos Reservoir Turnout</u> (Cap. 864 cfs to 767 cfs)				
Pipe	ft.	107,400	\$ 94.81	\$10,183,000
Excavation	cu.yd.	1,413,000	2.51	3,549,000
Backfill	cu.yd.	505,000	0.90	455,000
Tunnel	ft.	10,200	275.39	<u>2,809,000</u>
				\$16,996,000
<u>San Marcos Reservoir Turnout to Carroll Reservoir Turnout</u> (Cap. 644 cfs to 611 cfs)				
Pipe	ft.	97,400	89.61	8,728,000
Excavation	cu.yd.	780,000	2.41	1,880,000
Backfill	cu.yd.	433,000	0.90	<u>390,000</u>
				10,998,000
<u>Carroll Reservoir Turnout to Murray Reservoir Turnout</u> (Cap. 550 cfs to 534 cfs)				
Pipe	ft.	51,600	69.44	3,583,000
Excavation	cu.yd.	395,000	1.32	521,000
Backfill	cu.yd.	214,000	0.90	<u>193,000</u>
				4,297,000
<u>Murray Reservoir Turnout to Lower Otay Reservoir</u> (Cap. 368 cfs to 342 cfs)				
Pipe	ft.	75,400	64.66	4,876,000
Excavation	cu.yd.	1,858,000	1.05	1,954,000
Backfill	cu.yd.	286,000	0.90	<u>257,000</u>
				<u>7,087,000</u>
Subtotal				\$39,378,000
Reservoirs		lump sum		15,478,000
Major Laterals and Appurtenances		lump sum		<u>14,480,000</u>
Subtotal				\$69,336,000
Administration and engineering, 10%				\$ 6,934,000
Contingencies, 15%				10,400,000
Interest during construction				<u>2,718,000</u>
TOTAL ESTIMATED COST				\$89,388,000

"S" Line

The "S" line as described hereinafter generally follows the route studied by the San Diego County Water Authority and described in the aforementioned report of that agency issued in 1955. This line exhibited considerable merit in supplying supplemental water to those portions of San Diego County considered to have the greatest immediate potential for growth and attendant demand for water. The locations of the "S" line and required conveyance and regulatory storage facilities are shown on Plate 10B, entitled "Location of 'S' Line and Appurtenant Facilities".

Description of Route. The "S" line, as shown on Plate 10B, from the vicinity of Rainbow Pass would parallel the "E" line south to Rainbow Tunnel. As in the case of the "E" line, a tunnel would parallel the existing Rainbow Tunnel. From the south portal of the Rainbow Tunnel, the "S" line would continue parallel to the existing aqueduct southward to about two miles south of the San Luis Rey River. At this point, the line would depart from the existing aqueduct and would proceed southward generally parallel and about 1.5 to 2.5 miles westerly of the existing line to a crossing of the San Dieguito River just downstream from Hodges Dam. The line then would continue southward to a crossing of U. S. Highway 395 and would join the previously described "E" line just east of this crossing. From this point south to Lower Otay Reservoir, the "S" line would follow the same route as the "E" line as previously described.

Construction Problems. South of Rainbow Pass where the line would follow the general alignment of the existing San Diego Aqueduct to a point approximately two miles south of the San Luis Rey Valley, the difficulties in construction would be identical to those outlined for the "E" line above. From the point where the "S" line would swing west of the existing aqueduct to the

northerly limits of San Marcos Valley in the vicinity of Escondido, the alignment would traverse extremely rugged terrain. Access roads to the alignment exist only in the intersecting canyons, and it is expected that substantial site preparation would be required throughout the entire reach.

The alignment through the San Marcos Valley appears to offer little difficulty as far as construction is concerned. Good rail transportation facilities are provided by a railhead at San Marcos, which is easily reached from the alignment.

In the vicinity of Lake Hodges and southward, the character of the terrain again becomes rugged. The steep, rocky and rugged slopes west of Lake Hodges offer considerable difficulty to any type of construction. South of Lake Hodges and as far south as the site of the proposed Carroll Reservoir, which is a common intersecting point of all the lines discussed, there would be little difficulty in aqueduct construction. However, existing access roads into the area would require some improvement and additional roads would be required. From this latter point southward, the "S" line is identical to the "E" line.

Operation of "S" Line. As in the case of the "E" line, numerous locations for providing required regulatory storage capacity, with resulting variations in aqueduct size, were investigated and compared on a cost basis. As a result of these studies, it was found that storage should be provided in seven reservoirs. These reservoirs with required storage capacities are tabulated below and shown on Plate 10B.

<u>Reservoir</u>	<u>Capacity, in acre-feet</u>	<u>Maximum water surface elevation, in feet</u>
Vallecitos	10,000	938
San Marcos	16,000	421
Carroll	8,000	714
Woodson	8,000	775
Lower Otay	56,000	527
San Vicente	23,000	671
Murray	<u>6,000</u>	540
TOTAL	127,000	

It will be noted that construction of the "S" line would, by year 2000, require construction of 8,000 acre-feet of storage capacity at the Woodson site and 5,000 acre-feet of additional capacity at San Vicente Reservoir, both of which would not be required with construction of the "E" line. However, the "S" line would require only 56,000 acre-feet of additional capacity at Lower Otay Reservoir as compared with about 68,000 acre-feet of additional capacity required at this site for the "E" line. San Vicente Dam would be raised 21 feet and Lower Otay Dam would be raised 36 feet under this plan.

It will be noted from the foregoing tabulation as compared with the tabulation of storage required for the "E" line that the geographical distribution of storage required in the operation of the two lines would be substantially different. It will be further noted that the aggregate amount of storage required in the operation of each of the two lines differs by an amount of only 1,000 acre-feet.

Water service to Agua Tibia, Fallbrook, Camp Pendleton, and the north two-thirds of Rainbow Municipal Water District would be provided from the "S" line in a manner identical to that described for the "E" line. As stated, the location and hydraulic gradient of the two lines would be equivalent in this area. Laterals extending from Vallecitos Reservoir and to Agua Tibia and Fallbrook would be the same length as those described for the "E" line.

Lower Pauma Valley would be served a portion of its demand directly from the "S" line and the remaining portion from the existing aqueduct. Pauma Valley would be served directly from the existing aqueduct through a lateral which would also serve the remaining portion of the demand for Lower Pauma Valley. The new lateral from the existing San Diego Aqueduct extending up the Pauma Valley and the new lateral from the "S" line extending down the valley would have the same aggregate length as the laterals described for the "E" line. As was the case with the "E" line, Lower Pauma Valley and Pauma Valley could be served at grade line elevations of 500 and 1,100 feet, respectively, from these laterals without pumping.

The south one-third of Rainbow Municipal Water District would be served directly from the "S" line. At present this area has a lateral from the existing line extending to the easterly boundary of the area. This existing lateral together with a new lateral generally parallel to it and 2.2 miles in length would be connected to the "S" line. This area could be served at a grade line elevation of 600 feet without pumping.

The Valley Center Municipal Water District, Rincon del Diablo Municipal Water District, and the City of Escondido all would continue to receive water from the existing San Diego Aqueduct with construction of additional laterals as needed to meet future water demands. The areas could be served at grade line elevations of 1,100 feet, 1,000 feet, and 850 feet, from the existing aqueduct by gravity.

Bueno Colorado Municipal Water District would be served from the "S" line through a new lateral, 3.4 miles in length, which could deliver water at a grade line elevation of 900 feet without pumping.

Service would be provided directly from the "S" line to the Santa Fe Irrigation District, North of Santa Fe, Near Oceanside, portions of the demand of Oceanside and Carlsbad Municipal Water District through a new lateral

conveyance system 29.6 miles in length. The remaining portion of Oceanside's demand would be served as described for the "E" line through the existing Fallbrook-Oceanside Lateral. The remaining portion of Carlsbad Municipal Water District's demand and the demands for East of San Dieguito and San Dieguito would be provided in a manner identical to that described under the "E" line from laterals out of San Marcos Reservoir. Water deliveries could be accomplished without pumping, as with the "E" line.

The Rincon area would be served directly from the existing San Diego Aqueduct through a new lateral 1.7 miles in length. A pump lift of approximately 250 feet would be required to serve this area at a grade line elevation of 1,100 feet.

The area South of Lake Hodges could be served by gravity at a grade line elevation of 600 feet directly from the "S" line through a new lateral 0.6 mile in length.

The Ramona Municipal Water District and Poway Municipal Water District would be supplied directly from the existing San Diego Aqueduct during the months of low water demand; and during those months when water demand would be high and the flow in the aqueduct would be depleted, water would be pumped from the proposed Woodson Reservoir, which would have a minimum operating water surface elevation of 690 feet. Poway Municipal Water District could be served by gravity at a grade line elevation of 800 feet, from the aqueduct, and its supply would be pumped when being supplied from Woodson Reservoir. A new lateral 0.6 mile in length would be required to tie Poway Municipal Water District's existing conveyance system to Woodson Reservoir. A new lateral 5.7 miles in length and a pump lift of about 800 feet would be required to provide water service to Ramona at a grade line elevation of 1,500 feet.

Service from the "S" line to East of Del Mar, Camp Elliott, Near Miramar, the portion of the City of San Diego in this area, Rancho El Cajon,

El Capitan, Rio San Diego Municipal Water District, and San Vicente would be identical to that described for the "E" line with the exception that the lateral to East of Del Mar would be 1.1 miles in length rather than 3.2 miles as required for the "E" line.

By the year 2000 the remaining portion of City of San Diego and Helix Irrigation District would be served directly from the "S" line, and also from Murray Reservoir in the case of City of San Diego, therefore requiring no delivery of water from the existing San Diego Aqueduct. Service to these areas could be made at grade line elevations of 540 and 640 feet, respectively, by gravity.

South Bay Irrigation District and National City would be served both directly from the "S" line and from Lower Otay Reservoir. Delivery to this area from the "S" line at a grade line elevation of 400 feet could be made by gravity. Delivery at that elevation from Lower Otay Reservoir could be accomplished by a pump lift of up to 200 feet whereby water would be pumped back through the "S" line.

Otay Municipal Water District and Imperial would be served in a manner identical to that described for the "E" line.

Estimated Cost of "S" Line and Appurtenant Facilities. The preliminary estimate of cost of the "S" line and required regulatory storage and conveyance facilities is presented in Table 16.

TABLE 16

ESTIMATED COST OF "S" LINE TO MEET DEMAND FOR IMPORTED WATER TO
SAN DIEGO COUNTY IN YEAR 2000, INCLUDING REGULATORY RESERVOIRS
AND MAJOR LATERALS AND APPURTENANT FACILITIES

Item	Unit	Quantity	Unit price	Cost
Aqueduct Cost				
<u>Rainbow Pass to San Marcos Reservoir Turnout</u> (Cap. 864 cfs to 767 cfs)				
Pipe	ft.	114,800	\$100.51	\$11,539,000
Excavation	cu.yd.	1,410,000	2.23	3,146,000
Backfill	cu.yd.	543,000	0.90	489,000
Tunnel	ft.	5,200	272.69	<u>1,418,000</u>
				\$16,592,000
<u>San Marcos Reservoir Turnout to Carroll Reservoir Turnout</u> (Cap. 670 cfs to 648 cfs)				
Pipe	ft.	92,000	87.38	8,039,000
Excavation	cu.yd.	1,093,000	2.14	2,336,000
Backfill	cu.yd.	414,000	0.90	<u>373,000</u>
				10,748,000
<u>Carroll Reservoir Turnout to Murray Reservoir Turnout</u> (Cap. 588 cfs to 572 cfs)				
Pipe	ft.	51,600	73.47	3,791,000
Excavation	cu.yd.	366,000	1.29	471,000
Backfill	cu.yd.	222,000	0.90	<u>200,000</u>
				4,462,000
<u>Murray Reservoir Turnout to Lower Otay Reservoir</u> (Cap. 314 cfs to 288 cfs)				
Pipe	ft.	75,400	62.69	4,727,000
Excavation	cu.yd.	1,715,000	1.05	1,809,000
Backfill	cu.yd.	280,000	0.90	<u>252,000</u>
				<u>6,788,000</u>
Subtotal				\$38,590,000
Reservoirs		lump sum		16,452,000
Major Laterals and Appurtenances		lump sum		<u>13,212,000</u>
Subtotal				\$68,254,000
Administration and engineering, 10%				\$ 6,825,000
Contingencies, 15%				10,238,000
Interest during construction				<u>2,671,000</u>
TOTAL ESTIMATED COST				\$87,988,000

"W" Line

On the basis of preliminary study, it appeared desirable to give consideration to an aqueduct route farther to the west than that studied by the San Diego County Water Authority. Such a route would take advantage of less rugged terrain through part of its alignment, and would be located closer to the portion of the County with the greatest immediate potential demand for imported water. Location of an aqueduct in this area would reduce conveyance costs to the individual service areas while the hydraulic gradient in the aqueduct could be maintained equivalent to that of the other alternative routes making it possible to provide equivalent gravity water service. The locations of the "W" line and required appurtenant conveyance and regulatory storage facilities are shown on Plate 10C, entitled "Location of 'W' Line and Appurtenant Facilities".

Description of Route. The "W" line, as shown on Plate 10C, from the vicinity of Rainbow Pass generally parallels U. S. Highway 395 south through Rainbow Valley passing about one mile to the west of the proposed Vallecitos Reservoir. The line then runs nearly due south departing westward from the existing San Diego Aqueduct line up to a maximum distance of about seven miles westerly of the City of Escondido. From this point, the "W" line swings southeastward to a crossing of U. S. Highway 395 near the proposed Carroll Reservoir. From that point southward, the "W" line is identical with the previously described "E" and "S" lines.

Construction Problems. Construction of an aqueduct from Rainbow Pass south to San Luis Rey River along the "W" alignment could be accomplished with substantially less apparent major construction problems than would be encountered on the "E" or "S" lines. The point of crossing of the San Luis Rey River was

selected for its accessibility to two main highways. From a construction standpoint, this location appears to offer the least difficulties of locations considered. It appears that a substantial amount of backfill material throughout this entire reach could be provided from trench excavation.

In the portion of the alignment between San Luis Rey River and about three miles south of State Highway 78, some rock excavation would be required. Accessibility to the alignment from main and secondary roads is adequate and a minimum of site preparation would be required for pipe line construction. It is probable that a substantial amount of excavated trench material could be utilized for backfill. Railheads for necessary construction supplies and heavy equipment are available at San Marcos and Vista, which are within relatively short hauling distances of the alignment.

From the area south of State Highway 78 southward to the San Dieguito River, the alignment would pass through several miles of rugged terrain particularly in the vicinity of Escondido Creek. A considerable amount of rock excavation as well as hauling of imported backfill material would be necessary in this reach. However, access to this reach could be readily accomplished from existing secondary roads, with supplemental construction of additional required roads at relatively nominal cost.

The reach of the "W" line from San Dieguito River to the crossing of U. S. Highway 395 would encounter a minimum of construction problems. Backfill material could be made available from trench excavation and secondary access roads are available throughout the entire alignment; however, some improvements of these roads would be required.

Operation of "W" Line. As a result of economic studies of aqueduct operation relative to location of regulatory storage capacity and aqueduct size, it was concluded that those storage reservoirs and attendant capacities

enumerated for the "S" line would be most desirable for the "W" line. Except as hereinafter noted, water service throughout the area would be provided in essentially the same manner from the "S" and "W" lines.

Water service to Agua Tibia, Fallbrook, Camp Pendleton, and the north two-thirds of Rainbow Municipal Water District would be provided in a manner identical to that described for the "E" line with the exception that the common lateral to Camp Pendleton and Rainbow would divert water from the inlet-outlet line of Vallecitos Reservoir. New laterals extending from Vallecitos Reservoir would be the same length as those described for the "E" line. The new lateral to Fallbrook and the new lateral to Agua Tibia would be 0.4 and 1.7 miles in length, respectively.

Service to Pauma Valley and Lower Pauma Valley would be the same as that described for the "S" line. However, the new lateral from the "W" line to Lower Pauma Valley would be 1.9 miles in length.

Service to the south one-third of Rainbow Municipal Water District would be the same as from the "S" line. The new lateral to serve this area from the "W" line would be 1.3 miles in length.

The Valley Center Municipal Water District, Rincon del Diablo Municipal Water District, and Escondido would be served in an identical manner to that described under the "S" line.

Bueno Colorado Municipal Water District could be served directly from the "W" line at grade line elevation of 900 feet by gravity.

A portion of the demand for Oceanside and the demand for Near Oceanside areas would be served through a new lateral, 10.6 miles in length, diverting water from the "W" line. The remaining part of the demand for Oceanside would be served from the existing aqueduct through the existing Fallbrook-Oceanside Lateral. Delivery to these areas could be provided at grade line elevations of 400 and 300 feet, respectively, without pumping.

Rincon would be served in a manner identical to that described for the "S" line.

The South of Lake Hodges area would be served from the "W" line in the same manner as described for the "S" line with a new lateral 1.7 miles in length.

A portion of the demand for Carlsbad Municipal Water District, and the demands for North of Santa Fe and Santa Fe Irrigation District would be served as described for the "S" line but with a new lateral length of 5.5 miles from the "W" line to Carlsbad and a common new lateral 4.1 miles in length for North of Santa Fe and Santa Fe Irrigation District.

The remainder of the demand for Carlsbad Municipal Water District and the demands for East of San Dieguito, San Dieguito Irrigation District, and East of Del Mar would be provided with water in a manner identical to that described for the "E" line. The new laterals for Carlsbad Municipal Water District, East of San Dieguito, and San Dieguito Irrigation District would have the same lengths as for the "S" line and the new lateral for East of Del Mar would be 1.4 miles in length.

Delivery and lateral lengths from the "W" line and existing San Diego Aqueduct for Ramona Municipal Water District, Poway Municipal Water District, Rio San Diego Municipal Water District, Rancho El Cajon, San Vicente, El Capitan, Near Miramar, Camp Elliott, City of San Diego, Helix Irrigation District, South Bay Irrigation District and National City, Otay Municipal Water District, and Imperial would be identical to that described for the "S" line.

Estimated Cost of "W" Line and Appurtenant Facilities. Presented in Table 17 is the preliminary estimate of cost of the "W" line and required regulatory storage and conveyance facilities.

TABLE 17

ESTIMATED COST OF "W" LINE TO MEET DEMAND FOR IMPORTED WATER TO
SAN DIEGO COUNTY IN YEAR 2000, INCLUDING REGULATORY RESERVOIRS
AND MAJOR LATERALS AND APPURTENANT FACILITIES

Item	Unit	Quantity	Unit price	Cost
Aqueduct Cost				
<u>Rainbow Pass to San Marcos Reservoir Turnout</u> (Cap. 864 cfs to 728 cfs)				
Pipe	ft.	140,000	\$122.61	\$17,166,000
Excavation	cu.yd.	1,296,000	1.93	2,495,000
Backfill	cu.yd.	653,000	0.90	588,000
				\$20,249,000
<u>San Marcos Reservoir Turnout to Carroll Reservoir Turnout</u> (Cap. 670 cfs to 648 cfs)				
Pipe	ft.	77,000	99.96	7,697,000
Excavation	cu.yd.	637,000	2.37	1,508,000
Backfill	cu.yd.	343,000	0.90	309,000
				9,514,000
<u>Carroll Reservoir Turnout to Murray Reservoir Turnout</u> (Cap. 588 cfs to 572 cfs)				
Pipe	ft.	51,600	73.45	3,790,000
Excavation	cu.yd.	377,000	1.24	466,000
Backfill	cu.yd.	230,000	0.90	207,000
				4,463,000
<u>Murray Reservoir Turnout to Lower Otay Reservoir</u> (Cap. 314 cfs to 288 cfs)				
Pipe	ft.	75,400	62.69	4,727,000
Excavation	cu.yd.	1,715,000	1.05	1,809,000
Backfill	cu.yd.	280,000	0.90	252,000
				6,788,000
Subtotal				\$41,014,000
Reservoirs		lump sum		16,452,000
Major Laterals and Appurtenances		lump sum		11,025,000
Subtotal				\$68,491,000
Administration and engineering, 10%				\$ 6,849,000
Contingencies, 15%				10,274,000
Interest during construction				2,737,000
TOTAL				\$88,351,000

Summary Comparison of "E", "S", and "W" Lines

As a result of the foregoing analysis and investigation of costs and accomplishments of the considered routes, it was found that aqueducts, together with appurtenant facilities, required to regulate and convey water to areas of need, constructed on the "E", "S", or "W" lines would have equivalent over-all costs. Presented in Table 18 is a summary of the estimated costs of the three aqueducts and appurtenant works. It may be noted in Table 18 that although the over-all cost of each of the routes is equivalent, the cost of necessary conveyance units to serve areas of need varies between the routes, being the least for the "W" line.

TABLE 18

COMPARISON OF ESTIMATED COSTS OF AQUEDUCTS AND
APPURTENANT STORAGE AND CONVEYANCE FACILITIES
FOR THE "E", "S", AND "W" LINES

Item	: "E" Line	: "S" Line	: "W" Line
Aqueducts	\$39,378,000	\$38,590,000	\$41,014,000
Reservoirs	15,478,000	16,452,000	16,452,000
Major laterals and appurtenances	<u>14,480,000</u>	<u>13,212,000</u>	<u>11,025,000</u>
Subtotals	\$69,336,000	\$68,254,000	\$68,491,000
Administration and engineering, 10%	\$ 6,934,000	\$ 6,825,000	\$ 6,849,000
Contingencies, 15%	10,400,000	10,238,000	10,274,000
Interest during construction	<u>2,718,000</u>	<u>2,671,000</u>	<u>2,737,000</u>
TOTAL ESTIMATED COSTS	\$89,388,000	\$87,988,000	\$88,351,000

The investigation disclosed that, in addition to factors reflected in the cost estimates, each of the lines has inherent advantages and disadvantages relative to the others. Although each line would provide the same degree of water service at about the same cost, in the selection of a route for immediate construction, certain other factors should be taken into consideration.

The "E" line, by virtue of its proximity to the existing aqueduct, would lend itself to interconnection therewith at minimum expense and could easily be connected to existing conveyance systems, which factors would be of great advantage in aqueduct operation. However, as reflected in the estimate of cost, water service would be comparatively expensive for the area lying westerly of the "E" line, which area is considered to have the greatest immediate growth potential. The proximity to the existing aqueduct in itself offers one outstanding disadvantage, that of vulnerability of the entire imported water supply system for San Diego County in the event of enemy action during a war. Similarly, an act of God which could disrupt service in one line would in all probability affect the other. Also, as previously mentioned, construction difficulties would be encountered in certain areas particularly where the nature of the terrain fixes the location of the aqueduct within narrow limits and poses a hazard to the existing aqueduct during the construction period.

The "S" line, which lies to the west of the existing San Diego Aqueduct but closer to it than the "W" line, also could be cross connected to the existing aqueduct at a number of strategic locations at a lesser cost than for the "W" line. From the standpoint of proximity to the portion of the service area with the greatest potential immediate growth, it is considered superior to the "E" line. Its alignment offers, in certain areas, difficult construction problems and in those reaches where it is in close proximity to the existing aqueduct offers the same disadvantages as the "E" line with respect to vulnerability in times of national emergency or as a result of acts of God, and also with respect to possible damage to the existing aqueduct during the construction period.

The "W" line, which lies farther to the west, traverses that part of the service area which is considered to have the greatest immediate growth potential and attendant demand for water. Although construction of cross

connections with the existing aqueduct would be more costly, it is believed that this disadvantage would be more than outweighed by the over-all advantage to the westerly service area through lesser construction cost of conveyance facilities from the proposed aqueduct. The alignment traverses an area where, by comparison with the other two lines considered, construction problems would be at a minimum and which would be most accessible during construction and for maintenance thereafter, which factors may be expected to result in more rapid construction progress for the "W" line than for the "S" and "E" lines. Further, of the three lines considered, the "W" line lies farthest away from the existing San Diego Aqueduct reducing common vulnerability of the combination of existing and proposed aqueducts to breaks through acts of God or disruption of service in the event of enemy action during a war.

On the basis of the foregoing, it is considered that the "W" line is superior to the other lines studied in this investigation for the reach of the proposed San Diego Aqueduct between Rainbow Pass and Otay Reservoir.

Selection of Facilities for Initial Construction

It was concluded in foregoing sections of this chapter that the next aqueduct to San Diego County should originate at the westerly portal of San Jacinto Tunnel and extend southerly a distance of about 100 miles to a terminus southeast of the City of San Diego. It was further concluded that economics dictate construction of the aqueduct in canal section for the upper 29.5 miles of its length followed by a pipe line to the point of terminus. From the standpoints of ease and possible rapidity of construction and the cost of water service to that portion of the County with the greatest potential growth, it was concluded that the "W" or Westerly line below Rainbow Pass, shown on Plate 9, is superior to the other routes considered and that the next aqueduct to San Diego County should be constructed along this alignment. It has been stated

that, by the year 2000, about 150,000 acre-feet of regulatory storage capacity, distributed among eight sites along the existing and proposed aqueduct, will be needed for efficient operation of the existing and proposed facilities. However, until demands on the system exceed the peaking capacity thereof, construction of certain of these reservoirs could be deferred. Immediate construction of Auld Valley Reservoir is considered essential for emergency purposes to provide continuity of supply in the event of a breakdown or planned shutdown of the facilities of the Colorado River Aqueduct east of San Jacinto, and to provide regulation for continuous flow deliveries therefrom.

Presented in this section are the results of an analysis to determine the proper capacity of the aqueduct for an initial construction program which would be consistent with anticipated future demand for water in the service area thereof and with economic considerations related to staging of the pipe capacity. Also presented is an analysis of alternative plans for terminating the aqueduct at either the existing Otay Reservoir or the proposed Minnewawa Reservoir.

Analysis of Staged Construction of the Aqueduct

Determination of the aqueduct facilities which should be immediately constructed necessitated consideration of staged construction of the predominantly canal section between San Jacinto Tunnel and the Temecula River area and of the pipe line section south of Temecula River to the Otay Reservoir. The hydraulic characteristics and methods of construction of these two types of aqueducts are inherently different. As a result, conclusions reached relative to staging of facilities within the two sections may be expected to be at variance.

Canal Section. In order to arrive at the proper initial capacity of the canal section, detailed estimates of cost were prepared for two canal sections, and attendant siphons, with capacities of 500 second-feet and 1,000 second-feet, respectively, to Auld Valley Reservoir and 500 second-feet and 884 second-feet, respectively, from Auld Valley Reservoir to the beginning of the pipe line near Temecula River. Detailed estimates of cost on comparable bases were prepared for the foregoing two sizes of canal. A description of the larger installation is presented in Appendix B and the detailed cost estimate is reproduced in Appendix D. No detailed description or breakdown of the cost estimate for the smaller installation is herein presented but assumptions and criteria utilized in preparing it were the same as those utilized for the larger installation.

The estimated capital costs of the two sizes of canal installation extending from, but not including, the canal headworks, metering structure, and siphon near the west portal of the San Jacinto Tunnel to the end of the canal section near Temecula River and not including the cost of the bypass siphon at Auld Valley Reservoir, are presented in the following tabulation:

<u>Capacity, in second-feet</u>	<u>Estimated capital cost</u>
500	\$ 9,216,000
1,000 to 884	11,604,000

It will be noted from the foregoing tabulation that a 100 per cent increase in capacity from 500 to 1,000 second-feet would result in only an estimated 26 per cent increase in cost. As shown in Chapter II, by about the year 1981, it is estimated that the additional demand for imported water in the aqueduct service area will have reached 500 second-feet of continuous flow. The cost of a 500 second-foot canal constructed by the year 1981, discounted to present worth (1960) on a 3-1/2 per cent interest rate, would be about \$4,475,000

Adding this latter value to the \$9,216,000 capital cost of immediately installing a 500 second-foot canal installation results in a present worth of \$13,691,000 for the staged construction, as compared to a cost of \$11,604,000 for constructing the 1,000 second-foot canal immediately. On the basis of the foregoing, it was concluded that the initial capacity of the canal section should be that which would meet demands in the service area in year 2000, or 1,000 second-feet. It would be possible to reduce the initial construction cost somewhat by building only single barrels of considered two barrel siphons within the canal section. This saving, however, would not be appreciable and could be outweighed by costs arising from construction difficulties in the future when the second barrels were constructed. Further, the foregoing gives no consideration to probable increased construction costs or to increased value of lands required for right of way. Thus, on this basis, there would be an advantage of about two million dollars in favor of initial construction of the larger aqueduct.

Pipe Line Section. For purposes of comparative analyses of staged construction, preliminary estimates of cost were prepared for pipe lines having three different capacities, all of which would follow the "W" line from the end of the canal section to Lower Otay Reservoir. The pipe line stages considered had capacities of 864, 432, and 216 second-feet, all measured at the point of origin at the end of the canal section, with appropriately reduced capacity as the aqueducts proceeded southward. It is estimated that the pipe line with an initial capacity of 864 second-feet could provide for imported water demands in the aqueduct service area up to the year 2000 and that the 432 second-foot pipe line and the 216 second-foot pipe line could meet future water demands therein equal to one-half and one-quarter, respectively, of the total demands estimated for the year 2000. It is further estimated that the capacities of these latter

two pipe lines would be used up by the years 1981 and 1969, respectively, if either unit were constructed in the year 1960, and operated in conjunction with the existing San Diego Aqueduct.

The economic analysis of staged construction of the "W" line consisted of comparing the present worth of the estimated construction costs for the following combinations of installations:

1. Initial installation of a 864 second-foot pipe line in 1960.
2. Initial installation of a 432 second-foot pipe line in 1960 and an additional installation of a 432 second-foot pipe line in 1981.
3. Initial installation of a 432 second-foot pipe line in 1960 and additional installation of two 216 second-foot pipe lines in 1981 and 1989, respectively.
4. Initial installation of a 216 second-foot pipe line in 1960, additional installation of a 432 second-foot pipe line in 1969, and final addition of a 216 second-foot pipe line in 1989.
5. Installation of four 216 second-foot pipe lines in the years 1960, 1969, 1981, and 1989, respectively.

The costs of the foregoing combinations of pipe line installations are presented in Table 19. Present worths of the capital costs as of the year 1960 were computed on the basis of interest at 3-1/2 per cent per annum. It should be noted that all costs shown are on the same price basis regardless of the assumed date of construction. A continuation of the current and historical inflationary trend would give more advantage to the installation schedules involving the greatest immediate or near future expenditures.

TABLE 19

CAPACITIES AND PRESENT VALUES OF COSTS FOR COMBINATIONS
OF STAGED PIPE LINE CONSTRUCTION OF "W" LINE, BETWEEN
END OF CANAL SECTION AND LOWER OTAY RESERVOIR

Year	Single stage			Two Stage			Three Stage			Four Stage		
	Capacity, in	Present value, in	second- millions	Capacity, in	Present value, in	second- millions	Capacity, in	Present value, in	second- millions	Capacity, in	Present value, in	second- millions
	feet	of dollars	feet	of dollars	feet	of dollars	feet	of dollars	feet	of dollars	feet	of dollars
1960	864	57.2	432	39.6	432	39.6	216	27.0	216	27.0	216	27.0
1969							432	27.4	216	18.2		
1981			432	18.2	216	12.1			216	12.1		
1989					216	9.2	216	9.2	216	9.2		
2000												
TOTALS	864	57.2	864	57.8	864	60.9	864	63.6	864	66.5		

It is indicated in Table 19 that a two-stage construction of the pipe line would be essentially equivalent to initial construction to full capacity from an economic standpoint. It is believed to be conclusively demonstrated that either full or half capacity initial construction is definitely superior to construction of a quarter of full capacity initially or 216 second-feet.

Although initial construction of an aqueduct to supply half the demand in the year 2000 is equivalent from an economic standpoint to initial construction of an aqueduct that would supply the needs of the service area in the year 2000, two-stage construction would permit a re-evaluation of the proper location and capacity for the second stage of aqueduct construction from the experience and knowledge in the future as to pattern and rate of development. It is concluded, therefore, that the initial construction of the pipe line along the "W" line should provide for a capacity of 432 second-feet at its point of origin at the end of the canal section, with appropriate reduction of capacity as the aqueduct proceeds southward, which capacity operated with the existing aqueduct, would satisfy the estimated demand for imported water in the service area until the year 1981.

Economic Comparison of Alternative Plans for Terminating Aqueduct Facilities

Preliminary comparisons of the three alternative aqueduct routes and of staged construction of selected facilities were made on the basis of terminating each route at Lower Otay Reservoir. This reservoir was the point of terminus of the aqueduct route investigated by the San Diego County Water Authority and described in its report of 1955.

During the course of this investigation, further study was given to the location of a terminal reservoir and several alternative sites were given reconnaissance examination. As a result of the reconnaissance examination,

more detailed study was given to the raising of Lower Otay Dam, and to construction of a new dam at the Minnewawa site on Jamul Creek, a tributary of Otay River. The locations of the two sites are shown on Plate 9.

From previously described studies, it was concluded that in the year 2000, about 56,000 acre-feet of reservoir storage capacity at Lower Otay Reservoir or 59,000 acre-feet of reservoir storage capacity at the Minnewawa site would be required at the terminal reservoir for the "W" line. Provision for this amount of storage would require raising the existing Lower Otay Dam about 36 feet or to a maximum water surface elevation of 527 feet. The cost of raising the existing dam was estimated to be \$7,286,000. It should be emphasized that this cost is of a preliminary nature, and that a firm cost of such a plan would require a detailed design analysis, which is beyond the scope of this report.

Minnewawa Reservoir with a capacity of 59,000 acre-feet would require construction of a dam 175 feet in height from stream bed to spillway crest, and on the basis of earthfill construction was estimated to cost \$6,185,000. Further data relative to raising of Lower Otay Dam and construction of Minnewawa Dam are presented in Appendix D.

Since there would be a difference in the maximum water surface elevation in the two reservoirs of 173 feet, the slope of the hydraulic gradient in, and the size of, the proposed aqueduct to the north would vary according to the terminal reservoir selected. Further, this variance in hydraulic gradient also would affect the cost of service from the two alternative plans because pumping would be required to accomplish delivery to certain areas for the plan utilizing Otay Reservoir but not for the plan utilizing Minnewawa Reservoir. Proper comparison of the costs and accomplishments of the alternative systems therefore required consideration of not only dam and reservoir costs, but also the attendant costs of aqueducts, pumping plants, and energy required to accomplish water deliveries at the necessary hydraulic grade line elevations.

This comparison was made for the "W" line constructed with a capacity necessary to supply one-half the service area demand estimated for the year 2000, considered to be the requirement in the year 1981, and also for the additional aqueduct facilities needed to provide for the remaining half of the service area demand assuming that these latter facilities would be constructed by the year 1981. It was found that, depending on the terminal point selected, the size of aqueduct would be affected as far north as the vicinity of Vista near the point of turnout for the lateral to Oceanside. Also affected would be the cost of the lateral leading to Otay Municipal Water District and Imperial. The comparison was made on the basis of present worth of capital costs of construction items and of annual costs of operation, maintenance, and replacements for pumping facilities including power costs in perpetuity. The present worth computations were based on an interest rate of 3-1/2 per cent per annum. The results of the comparison are set forth in Table 20.

It will be noted in Table 20 that, from the standpoint of cost, there would be an advantage of about \$2,200,000 in favor of the aqueduct terminating at Lower Otay Reservoir rather than Minnewawa Reservoir. There are, however, certain other factors not susceptible of economic evaluation which should be considered in making a choice between the two points of terminus.

Although, on the basis of studies described hereinbefore, the City of San Diego and Helix Irrigation District would not require delivery of aqueduct water from either Lower Otay Reservoir or the proposed Minnewawa Reservoir, variations in the pattern of development from that indicated in the demand studies would result in the need for delivery of water thereto from Minnewawa Reservoir by reversing the direction of flow in the main aqueduct. Such delivery could be accomplished by gravity from Minnewawa Reservoir but would require pumping from Lower Otay Reservoir.

ECONOMIC COMPARISON OF ALTERNATIVE PLANS FOR CONVEYANCE AND STORAGE
FACILITIES IN THE TERMINAL REACH OF THE PROPOSED SAN DIEGO AQUEDUCT

Costs associated with terminating in Lower Otay Reservoir including aqueduct costs, Station 2721+00 to Station 5320+00		Costs associated with terminating in Minnewawa Reservoir including aqueduct costs, Station 2721+00 to Station 5522+00	
Item	: Capital cost : Present worth :	Item	: Capital cost : Present worth :
Initial stage of pipe line constructed in 1960	\$25,500,000	Initial stage of pipe line constructed in 1960	\$31,000,000
Lateral to Otay M.W.D. and Imperial	2,900,000	Lateral to Otay M.W.D. and Imperial	3,000,000
Enlarged Lower Otay Dam and Reservoir	7,300,000	Minnewawa Dam and Reservoir	6,200,000
Pumping plant	500,000 ^a		
Replacement, operation, and maintenance	500,000 ^b		
Pumping energy	<u>1,000,000^b</u>		
Subtotals	37,600,000		40,200,000
Second stage of pipe line constructed in 1981	23,300,000	Second stage of pipe line constructed in 1981	30,500,000
Pumping plant	500,000 ^a		
Replacement, operation, and maintenance	400,000 ^b		
Pumping energy	<u>3,300,000^b</u>		
Subtotals	15,200,000		14,800,000
TOTALS	\$52,800,000		\$55,000,000

a. Pumping units installed in two stages at approximately 10-year intervals.

b. Present worth of future annual pumping costs based upon varying future water demands.

The greatest advantage of Minnewawa Reservoir is considered to be its utility in serving the distribution systems of the City of San Diego, Helix Irrigation District, and National City and South Bay Irrigation District during an emergency or a planned shutdown of the aqueduct north of Murray Reservoir. The minimum operating water surface elevation of the proposed Minnewawa Reservoir is 615 feet and the elevation of the turnout to Lake Murray on the proposed aqueduct line would be about 580 feet. Therefore, water stored in Minnewawa Reservoir could, if required, be fed back through the aqueduct by gravity at rates of from 100 to 200 second-feet depending on the water surface elevations in the former reservoir. It should be noted further that water could also be delivered by gravity from Minnewawa Reservoir into the existing Sweetwater Reservoir of the California Water and Telephone Company on Sweetwater River. This would not be possible from Lower Otay Reservoir. It is, therefore, concluded that the construction of Minnewawa Reservoir would add a substantial degree of assurance of continuity of water service in the event of emergency shutdown of the aqueduct, and would permit flexibility and coordination of operation of the storage and conveyance system of the City of San Diego and of the California Water and Telephone Company for utilization of imported water from the north.

It should again be emphasized that a detailed design analysis of the plan for raising Lower Otay Reservoir, which would be required for a firm estimate of cost therefor, was beyond the scope of this investigation, and that the estimated cost of Minnewawa Dam and Reservoir is considered to be the more realistic of the two. Prior to final selection of one of the two alternatives, additional engineering investigation should be undertaken at both of the sites to more closely ascertain the difference in cost between the alternative plans.

Timing of Reservoir and Aqueduct Construction

As previously stated, with the construction of the initial unit of the proposed aqueduct to San Diego County, construction of certain of the reservoirs required for operation in the year 2000 may be deferred. By operating Auld Valley Reservoir, to be constructed initially, together with the existing Murray Reservoir and by operating the existing San Diego Aqueduct to full capacity with attendant regulatory storage in San Vicente Reservoir, it would be possible to meet the demands of the potential water service area until about 1975. It appears that at that time additional regulatory storage would be required which could be provided by the construction of either Minnewawa Reservoir or the combination of San Marcos, Vallecitos, and Carroll Reservoirs. If Minnewawa Reservoir or the combination of San Marcos, Vallecitos, and Carroll Reservoirs were constructed at that time, it would be possible to provide for service area water requirements from the existing and proposed aqueducts until 1981, at which time the second stage of aqueduct construction would be required. By constructing the foregoing three smaller reservoirs as well as Minnewawa Reservoir between 1970 and 1980, the second stage of aqueduct construction could only be deferred about two years. It should be noted that it may be desirable to construct certain of the afore-mentioned reservoirs prior to the time they would be needed for regulation of aqueduct water to provide emergency storage, or to give more flexibility to the aqueduct operation.

If the construction of Minnewawa Reservoir were not accomplished until 1975 or later as just discussed, it would not be necessary to construct the three-mile section of the aqueduct between Lower Otay Reservoir and Minnewawa Reservoir until such time as the reservoir is required. However, until increased water demands create the need for regulatory storage of Minnewawa Reservoir, water service could still be provided to Otay Municipal

Water District and Imperial by deliveries from the end of the aqueduct without pumping, prior to construction of Minnewawa Reservoir and the foregoing terminal reach of aqueduct. In the interim until these latter facilities were built, any excess flows in the aqueduct could be discharged into Lower Otay Reservoir.

Summary of Facilities Selected for Initial Construction

The facilities selected for initial construction and their estimated capital costs, including allowance of 10 per cent for engineering and 15 per cent for contingencies as well as an allowance for interest during construction, are shown in the following tabulation:

San Jacinto Tunnel to End of Canal Section

Type of conduit - Canal
Capacity - 1,000-884 second-feet
Length - 29.5 miles
Capital Cost - \$13,045,000

End of Canal Section to Proposed Minnewawa Reservoir Site

Type of conduit - Reinforced concrete and steel pipe
Capacity - Maximum 432 second-feet diminishing to
93 second-feet at terminus
Length - 74.5 miles
Capital Cost - \$52,786,000

Auld Valley Reservoir

Type of dam - Earthfill
Height of dam to spillway - 85 feet
Gross reservoir capacity - 38,000 acre-feet
Purpose - Regulation and emergency storage
Capital Cost - \$6,053,000

Total Capital Cost

\$71,880,000

It will be noted that the foregoing facilities include a pipe line leading all the way to the proposed Minnewawa reservoir site. As previously discussed, it will probably not be necessary to construct Minnewawa Reservoir

for a number of years. Therefore, the section of pipe line between Otay Reservoir and the inlet to Minnewawa Reservoir would not be necessary for initial construction. The capital cost of this section of pipe line is estimated to be \$2,630,000.

The foregoing facilities of the proposed San Diego Aqueduct selected for initial construction are described in detail in Appendix B of this report. Plan and profile for the aqueduct line are shown on Plate 24, entitled "Plan and Profile", and typical aqueduct structures and appurtenances including Auld Valley Dam and Reservoir shown on Plates 11 through 21.

Presented in Appendix D is a detailed estimate of the capital costs of the initial features described in Appendix B and based upon unit prices shown in Appendix C. A summary of the detailed cost estimate is presented in Table 21.

The facilities shown in Table 21 operated coordinately with the existing San Diego Aqueduct could supply the estimated demands for imported water in the potential aqueduct service area until about the year 1975. With construction of Minnewawa Reservoir with a capacity of 59,000 acre-feet, the foregoing facilities could supply the estimated water demands until about 1981. The method of delivery of water from the existing and proposed aqueducts as estimated for the year 1980 is illustrated on Plate 25, entitled "Schematic Diagram of Estimated Annual Water Deliveries from the Existing San Diego Aqueduct and from Proposed 'W' Line in the Year 1980".

It should be noted that the canal section of the foregoing aqueduct facilities, with a design capacity ranging from 1,000 to 884 second-feet, would have sufficient capacity to convey, as far as the vicinity of Temecula River, the water needed in the potential service area estimated for the year 2000. However, conveyance of the additional water supplies estimated to be needed south of Temecula River after about the year 1980 would require the construction

of the second stage of the pipe line section of the aqueduct which would have a capacity ranging from 432 second-feet to 98 second-feet and would essentially parallel the pipe line route selected for initial construction, as well as Vallecitos, San Marcos, Carroll, and Woodson Reservoirs with an aggregate storage capacity of 42,000 acre-feet. The method of delivery of water from the existing and proposed aqueducts as estimated for the year 2000 is illustrated on Plate 26, entitled "Schematic Diagram of Estimated Annual Water Deliveries from the Existing San Diego Aqueduct and from Proposed 'W' Line in the Year 2000".

TABLE 21

SUMMARY OF
ESTIMATED COST OF INITIAL FEATURES OF
PROPOSED SAN DIEGO AQUEDUCT FROM SAN JACINTO
TUNNEL TO PROPOSED MINNEWAWA RESERVOIR SITE
"W" LINE

(Based on prices prevailing in the fall of 1956)

Station	:	Item	:	Cost
0+00 to 17+50		San Jacinto Tunnel to Beginning of Canal, Capacity 1,000 cfs		\$ 872,600
17+50 to 1202+00		From Beginning of Canal to Auld Valley Reservoir, Capacity 1,000 cfs		6,246,000
		Auld Valley Reservoir, Capacity 38,000 acre-feet		4,701,600
1202+00 to 1245+50		Auld Valley Reservoir Bypass Siphon, Capacity 442 cfs		218,800
1245+50 to 1586+75		From Auld Valley to Beginning of Pipe Line, Canal Capacity 884 cfs		2,633,600
1586+75 to 2100+00		Pipe Line from End of Canal to Vallecitos Reservoir Turnout, Capacity 432 cfs		5,205,600
2100+00 to 2721+00		Turnout (Vallecitos Reservoir) to Turnout (Oceanside), Capacity 394 cfs		7,620,900
2721+00 to 2945+00		Turnout (Oceanside) to Turnout (Bueno Colorado), Capacity 383 cfs		2,286,800
2945+00 to 3163+00		Turnout (Bueno Colorado) to Turnout (Carlsbad), Capacity 374 cfs		2,258,000
3163+00 to 3269+00		Turnout (Carlsbad) to Turnout (San Marcos Reservoir), Capacity 364 cfs		1,182,700
3269+00 to 3861+00		Turnout (San Marcos Reservoir) to Turnout (East of Del Mar), Capacity 335 cfs		6,713,800
3861+00 to 4043+00		Turnout (East of Del Mar) to Turnout (Carroll Reservoir), Capacity 324 cfs		1,849,000
4043+00 to 4214+00		Turnout (Carroll Reservoir) to Turnout (Camp Elliott), Capacity 294 cfs		1,778,200
4214+00 to 4614+00		Turnout (Camp Elliott) to Turnout (San Diego and Helix), Capacity 286 cfs		3,524,100

SUMMARY OF
ESTIMATED COST OF INITIAL FEATURES OF
PROPOSED SAN DIEGO AQUEDUCT FROM SAN JACINTO
TUNNEL TO PROPOSED MINNEWAWA RESERVOIR SITE
"W" LINE
(continued)

Station	:	Item	:	Cost
4614+00 to 4995+00		Turnout (San Diego and Helix) to Turnout (South Bay and National City), Capacity 157 cfs		\$ 3,557,300
4995+00 to 5274+00		Turnout (South Bay and National City) to Turnout (Otay and Imperial), Capacity 144 cfs		2,406,000
5274+00 to 5522+00		Turnout (Otay and Imperial) to Minnewawa Reservoir, Capacity 98 cfs		<u>1,963,600</u>
Subtotal				\$55,018,600
Administration and engineering, 10%				\$ 5,501,900
Contingencies, 15%				8,252,800
Interest during construction				<u>3,111,500</u>
TOTAL				\$71,884,800

CHAPTER IV. CONCLUSIONS AND RECOMMENDATIONS

The following conclusions and recommendations are submitted with reference to the investigation of alternative Feather River Project Aqueduct routes to San Diego County.

Conclusions

As a result of the investigation, it is concluded that:

1. San Diego County is faced with a critical water problem requiring construction of additional aqueduct capacity to supply imported water to the County at the earliest practicable date.
2. This aqueduct must be so located as to serve presently surplus Colorado River water in the interim until Feather River Project water can be made available, and this location should be that which will provide maximum water service at minimum over-all cost.
3. Determination of the location of a route for the Feather River Project Aqueduct through San Bernardino and Riverside Counties, pursuant to the directive of Senate Concurrent Resolution No. 19, must await completion of current studies of alternative Feather River Project Aqueduct routes to southern California.
4. The aqueduct should be constructed initially to the most economical size that will provide sufficient water for the growth of southwestern Riverside County and San Diego County for a reasonable period in the future.
5. By year 2000, with provision for an adequate water supply, it is estimated that there will be about 2,800,000 people in San Diego County, 80 per cent of which would be located in the San Diego Metropolitan Area, and that the present area of irrigated agriculture may have expanded about 300 per cent to about 210,000 acres in San Diego and southwestern Riverside Counties.

6. The requirement for imported water in southwestern Riverside and San Diego Counties, in addition to the 141,000 acre-feet per year obtained through the existing aqueduct, may approach 800,000 acre-feet annually by year 2000.

7. The rate of increase in demand for imported water in San Diego and southwestern Riverside Counties, herein estimated, coupled with ever increasing demands for imported water in the remainder of the service area of The Metropolitan Water District of Southern California, emphasizes the need for rapidity of action in construction of the Feather River Project.

8. The over-all future demand for water in the potential aqueduct service area will be influenced only to a relatively small degree by those factors of aqueduct location and price within the limits and assumptions of the investigation.

9. The aqueduct should originate at the westerly portal of San Jacinto Tunnel and from this point to the vicinity of Temecula River, a distance of about 29.5 miles, should be constructed as a canal with a substantial saving in costs over pipe line construction. The remaining 74.5 miles of aqueduct to a terminus in the proposed Minnewawa Reservoir would be of pipe line construction comprising sections of both reinforced concrete pipe and steel pipe.

10. Because of the relatively small increment in cost of construction of successively larger canal capacities, amounting to only about 26 per cent in the increment between 500 second-feet and 1,000 second-feet, the canal section should be constructed initially to supply demands in the potential aqueduct service area in the year 2000 or with a capacity of about 1,000 second-feet.

11. Economic comparison of lines "E", "S", and "W", which routes were given detailed consideration, including evaluation of the cost of regulatory storage capacity and of major laterals necessary to provide water service to

existing and potential water service agencies, indicates no clear cut advantage of one route over the others.

12. Although equivalent in over-all cost to the other routes considered, the Westerly or "W" route is deemed superior from the standpoints of ease and rapidity of construction and of the cost of necessary conveyance facilities to serve that portion of the service area with the greatest potential future water demand.

13. Construction of the "W" line should provide for a capacity of 432 second-feet at a point of origin at the end of the canal section, with appropriate reduction of capacity as the aqueduct proceeds southward, which capacity when operated coordinately with the existing San Diego Aqueduct would satisfy the estimated demand for imported water in the potential service area until about the year 1981.

14. A two stage construction of the aqueduct is not only desirable from an economic standpoint but will also permit a re-evaluation of the proper location and capacity for the second stage of aqueduct construction with the experience and knowledge of the future as to pattern and rate of development.

15. Auld Valley Reservoir adjacent to the canal section on Tualota Creek should be constructed initially with a capacity of about 38,000 acre-feet as an aqueduct appurtenance to provide flexibility of operation and desirable emergency storage near the upper portion of the aqueduct.

16. By year 2000, regulatory storage capacity of about 150,000 acre-feet will be required for economical aqueduct operation. The required storage capacity, in addition to that provided at Auld Valley Reservoir, should be distributed as follows:

<u>Reservoir</u>	<u>Capacity, in acre-feet</u>
Vallecitos	10,000
San Marcos	16,000
Carroll	8,000
Woodson	8,000
Minnewawa	59,000
San Vicente	23,000*
Murray	6,000**

*Portion of capacity of existing reservoir.

**Existing reservoir.

17. Construction of certain of the regulatory reservoirs other than Auld Valley may be deferred until such time as peak demands on the aqueduct exceed capacity therein.

18. Features of the proposed San Diego Aqueduct to be constructed initially, estimated to have a cost of \$71,880,000, are summarized as follows:

San Jacinto Tunnel to End of Canal Section

Type of conduit - Canal
Capacity - 1,000-884 second-feet
Length - 29.5 miles
Capital Cost - \$13,045,000

End of Canal Section to Proposed Minnewawa Reservoir Site

Type of conduit - Reinforced concrete and steel pipe
Capacity - Maximum 432 second-feet diminishing to
98 second-feet at terminus
Length - 74.5 miles
Capital Cost - \$52,786,000

Auld Valley Reservoir

Type of dam - Earthfill
Height of dam to spillway - 85 feet
Gross reservoir capacity - 38,000 acre-feet
Purpose - Regulation and emergency storage
Capital Cost - \$6,053,000

19. The Metropolitan Water District of Southern California and the San Diego County Water Authority intend to proceed with the financing and constructing of an aqueduct to San Diego County and that this aqueduct would follow an alignment generally equivalent to that considered herein but would have a capacity of 500 second-feet in the canal section and a capacity in the initial pipe line section of 250 second-feet.

Recommendations

As a result of this investigation, it is recommended that:

1. In view of the estimates of future water requirements in San Diego and southwestern Riverside Counties and economic analyses relative to initial aqueduct capacity, presented in this report, immediate steps be taken to construct the proposed San Diego Aqueduct with a capacity varying from 1,000 to 884 second-feet in the canal section, and a capacity varying from 432 to 98 second-feet in the pipe line section.

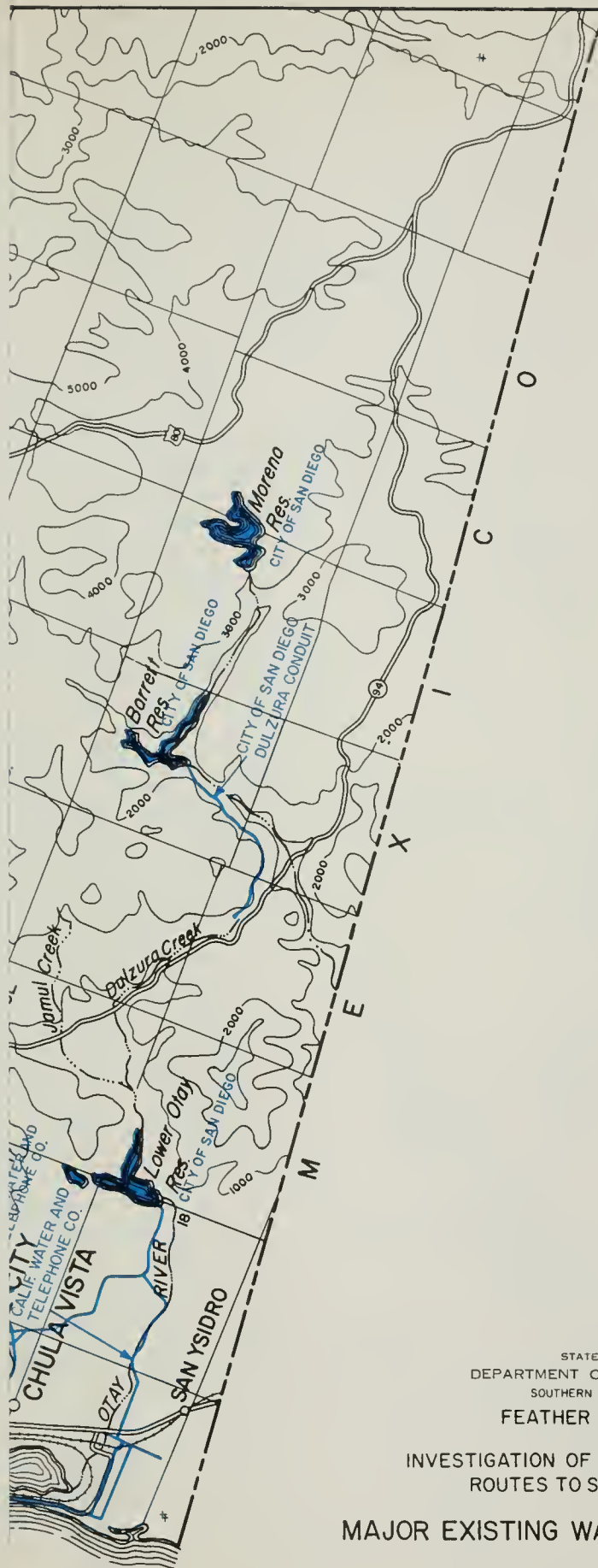
2. Responsible local agencies give continuing support to immediate construction of the Feather River Project and to future units of The California Water Plan which will be needed for satisfaction of forecast water requirements in the South Coastal Area including San Diego County.

INVESTIGATION OF ALTERNATIVE AQUEDUCT ROUTES TO SAN DIEGO COUNTY

LOCATION OF INVESTIGATIONAL AREA
1957



STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT
FEATHER RIVER PROJECT
INVESTIGATION OF ALTERNATIVE AQUEDUCT
ROUTES TO SAN DIEGO COUNTY
LOCATION OF INVESTIGATIONAL AREA
1957



STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT

FEATHER RIVER PROJECT

INVESTIGATION OF ALTERNATIVE AQUEDUCT
ROUTES TO SAN DIEGO COUNTY

MAJOR EXISTING WATER SUPPLY FACILITIES
1957

SCALE OF MILES





STATE OF CALIFORNIA
 DEPARTMENT OF WATER RESOURCES
 SOUTHERN CALIFORNIA DISTRICT
 FEATHER RIVER PROJECT
 INVESTIGATION OF ALTERNATIVE AQUEDUCT
 ROUTES TO SAN DIEGO COUNTY
 MAJOR EXISTING WATER SUPPLY FACILITIES
 1957

SCALE OF MILES

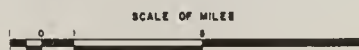


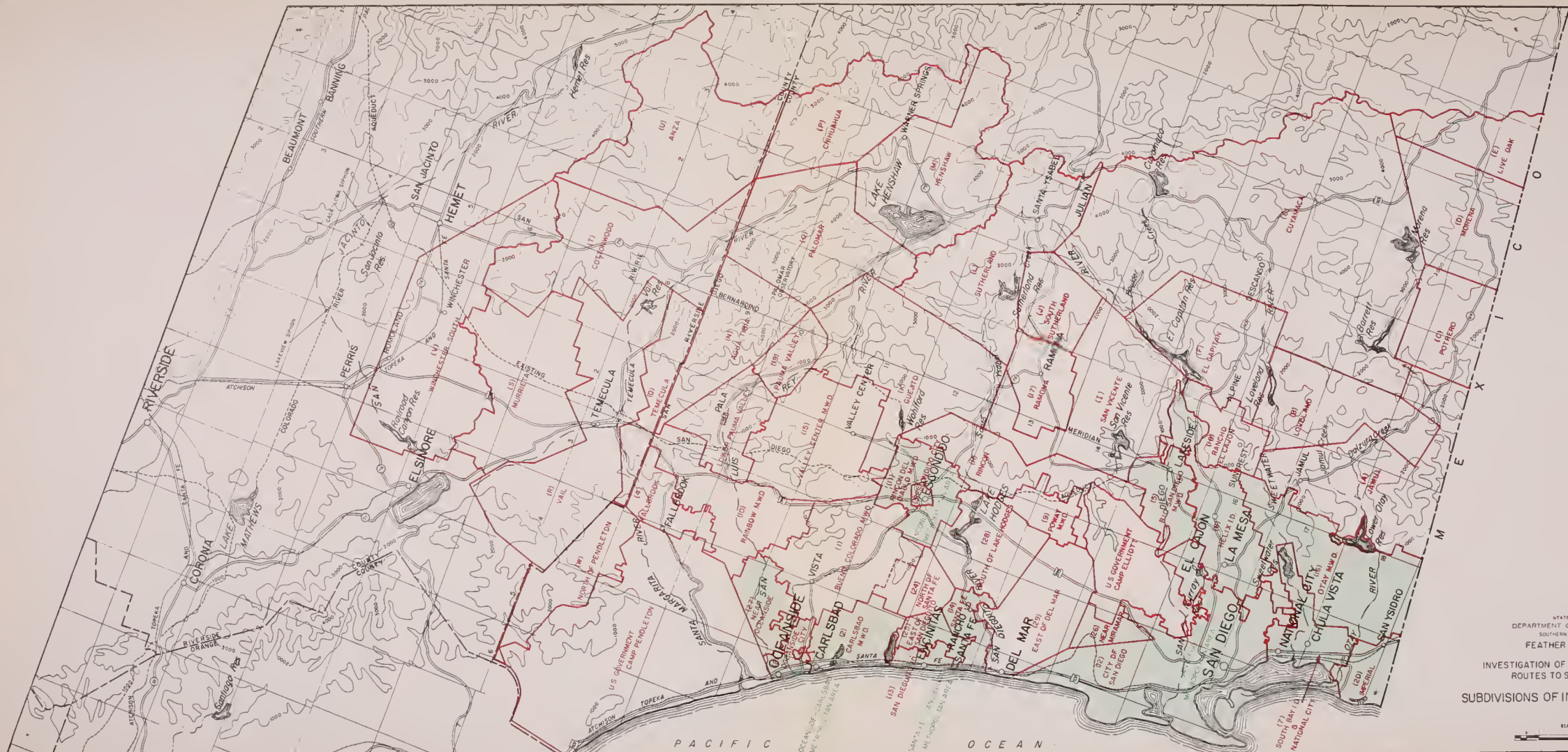
STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT
FEATHER RIVER PROJECT

INVESTIGATION OF ALTERNATIVE AQUEDUCT
ROUTES TO SAN DIEGO COUNTY

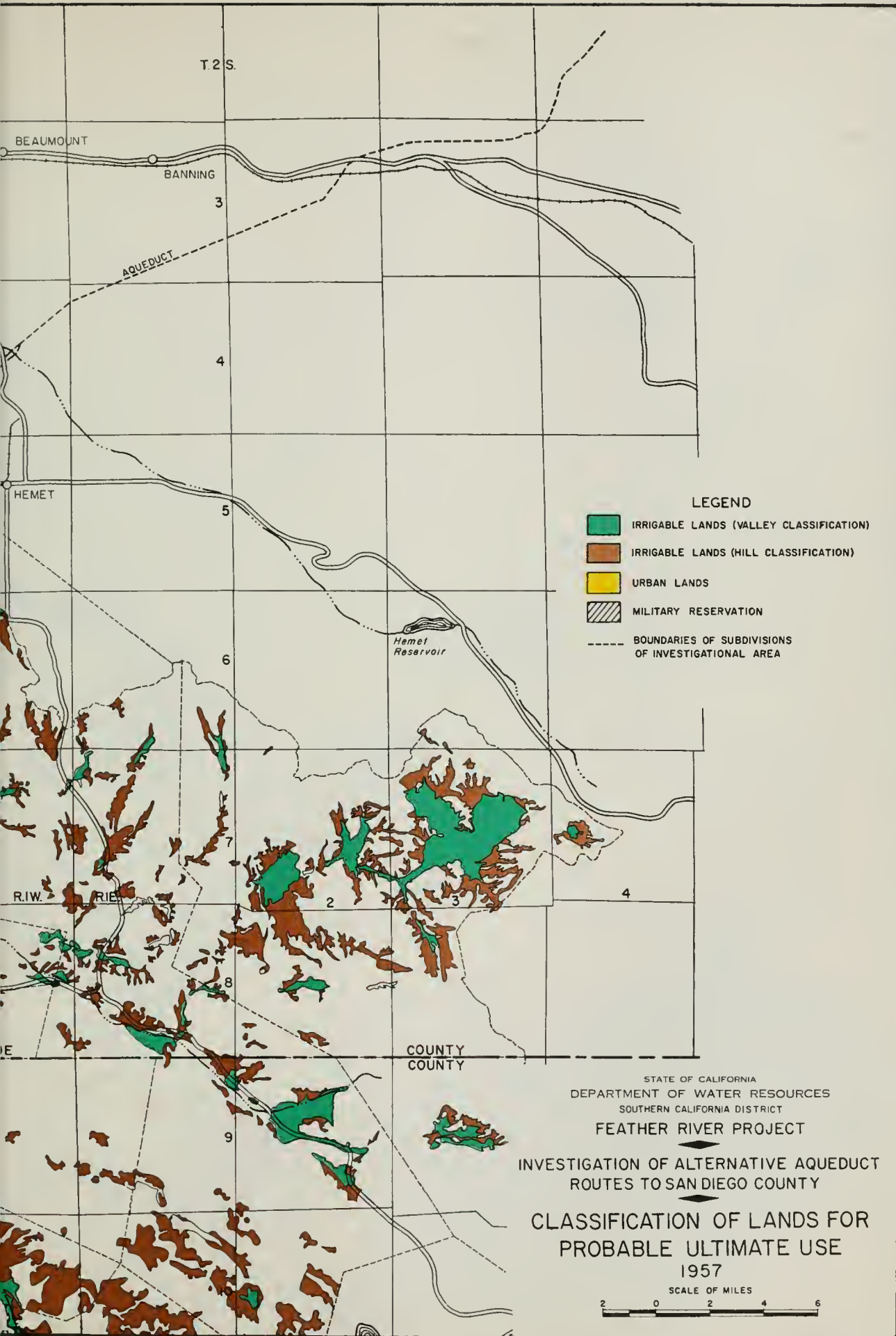
SUBDIVISIONS OF INVESTIGATIONAL AREA

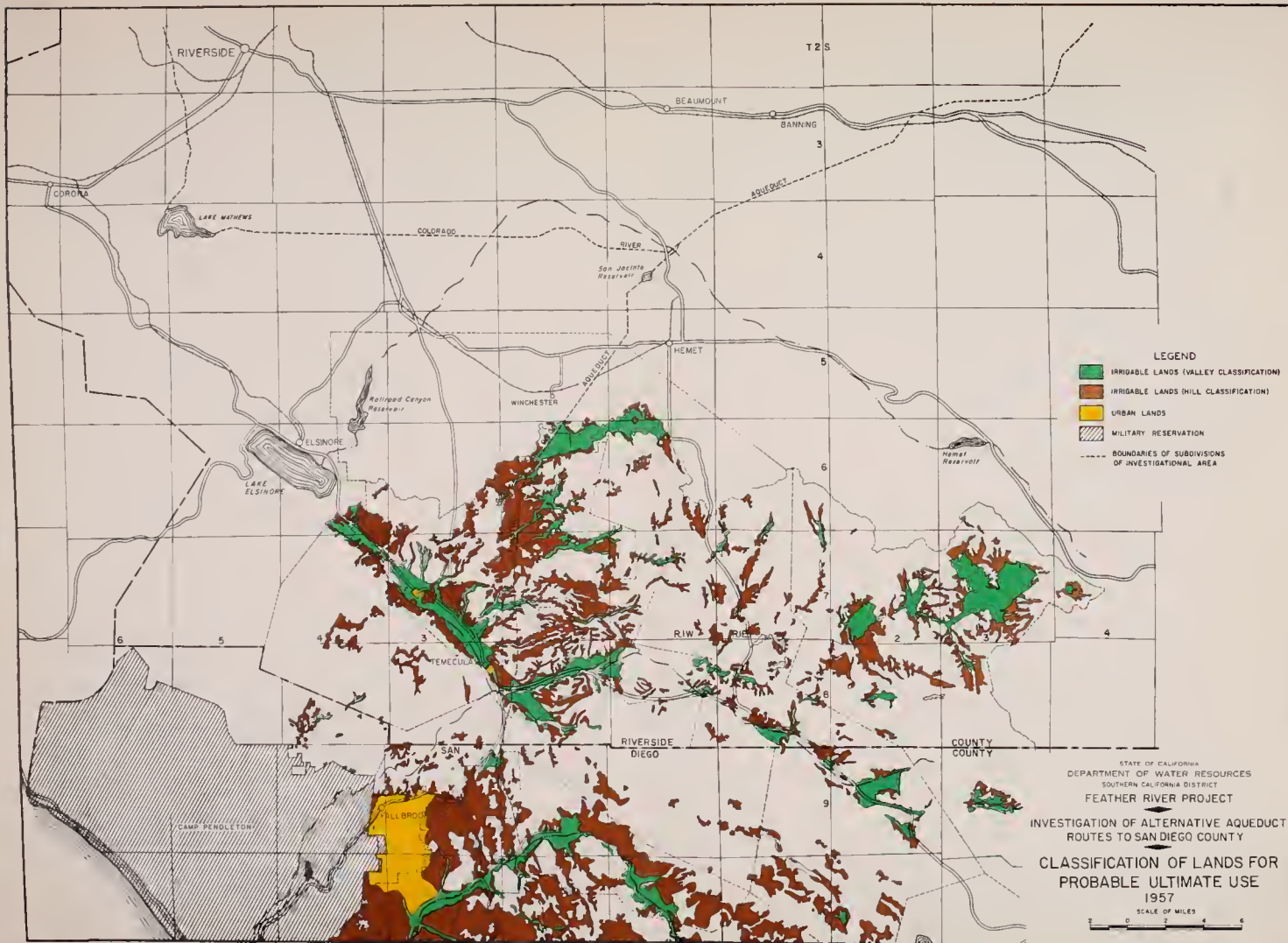
1957

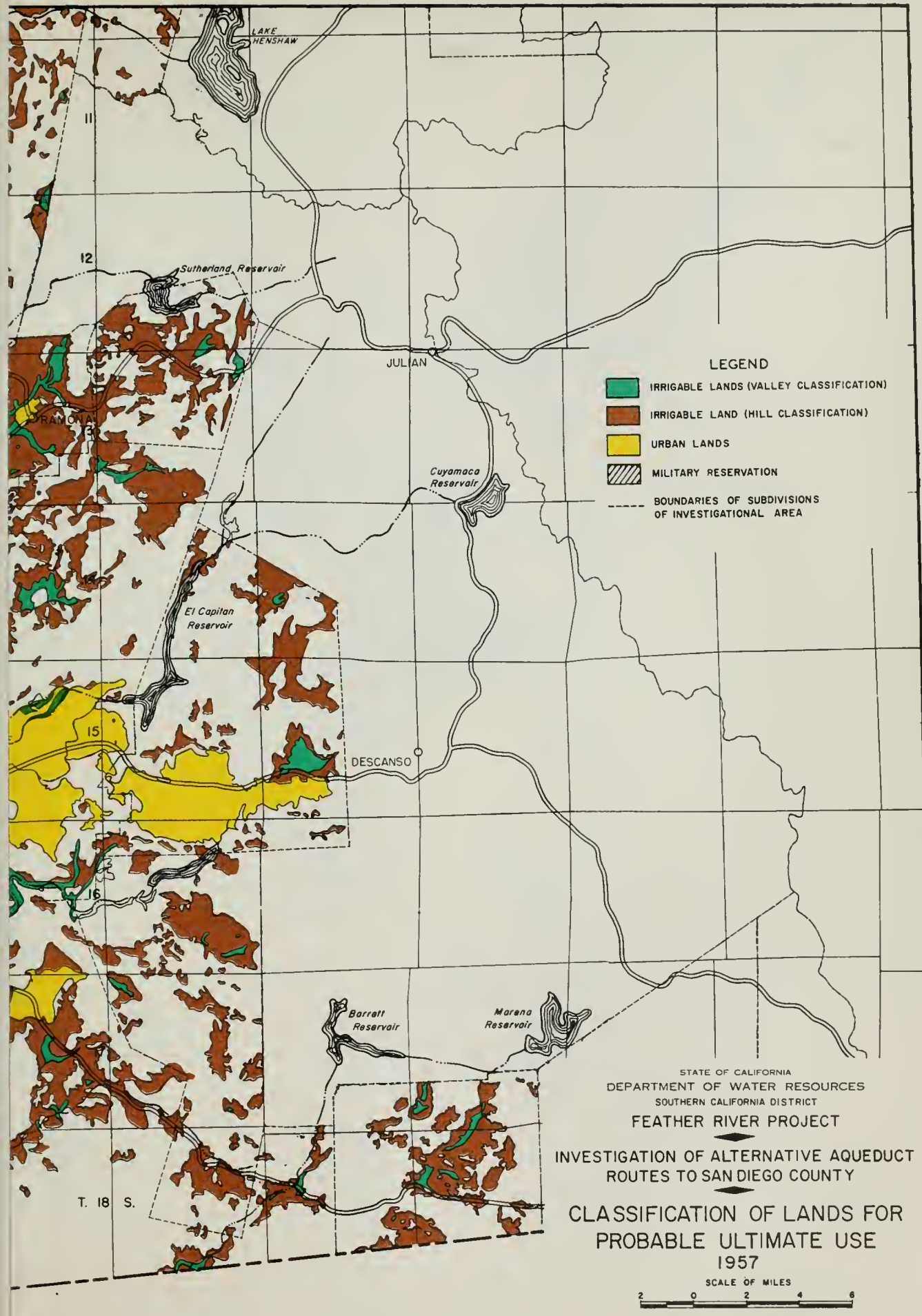




STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT
FEATHER RIVER PROJECT
INVESTIGATION OF ALTERNATIVE AOUEDUCT
ROUTES TO SAN DIEGO COUNTY
SUBDIVISIONS OF INVESTIGATIONAL AREA
1957
SCALE 1" = 10 MILES



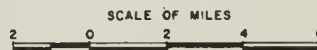


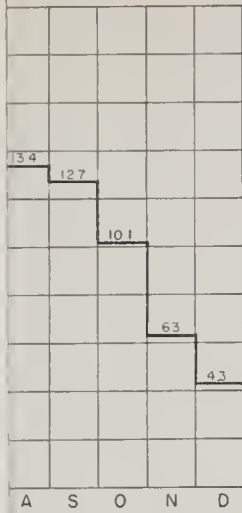


LEGEND

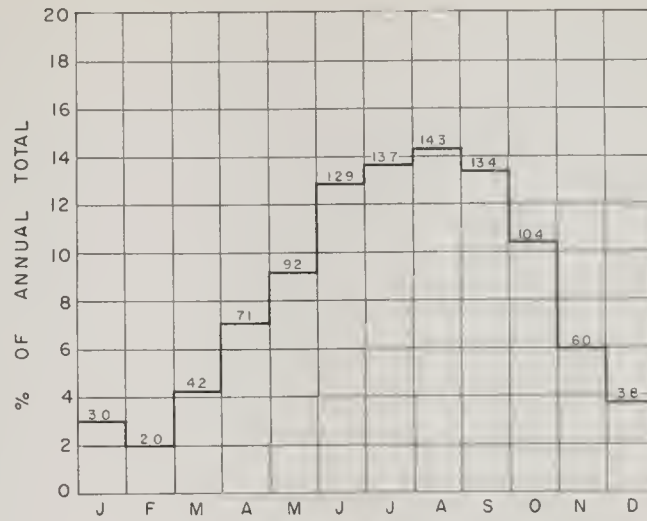
- IRRIGABLE LANDS (VALLEY CLASSIFICATION)
- IRRIGABLE LAND (HILL CLASSIFICATION)
- URBAN LANDS
- MILITARY RESERVATION
- BOUNDARIES OF SUBDIVISIONS OF INVESTIGATIONAL AREA

STATE OF CALIFORNIA
 DEPARTMENT OF WATER RESOURCES
 SOUTHERN CALIFORNIA DISTRICT
 FEATHER RIVER PROJECT
 INVESTIGATION OF ALTERNATIVE AQUEDUCT
 ROUTES TO SAN DIEGO COUNTY
 CLASSIFICATION OF LANDS FOR
 PROBABLE ULTIMATE USE
 1957

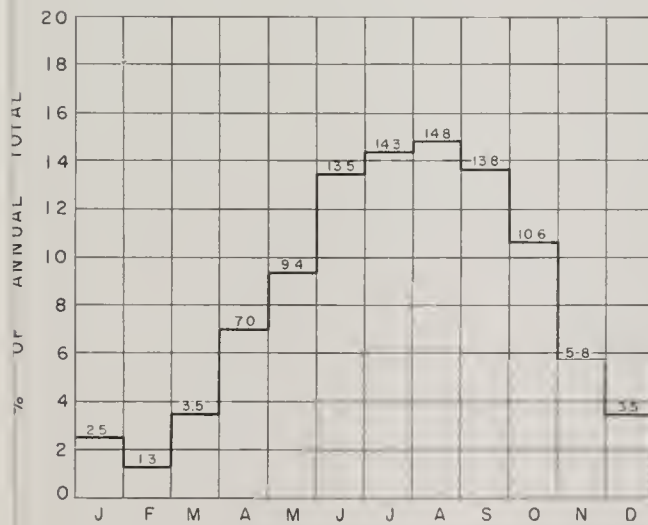




WATER DISTRICT



RAMONA M.W.D., MURRIETA AREA,
WINCHESTER SOUTH AREA,
AGUA TIBIA AREA



RAINBOW M.W.D., VALLEY CENTER M.W.D.,
PAUMA VALLEY AREA, LOWER PAUMA VALLEY
AREA, NORTH OF SANTA FE AREA,
SOUTH OF LAKE HODGES AREA

PER CENT OF ANNUAL DEMAND

PLATE 5

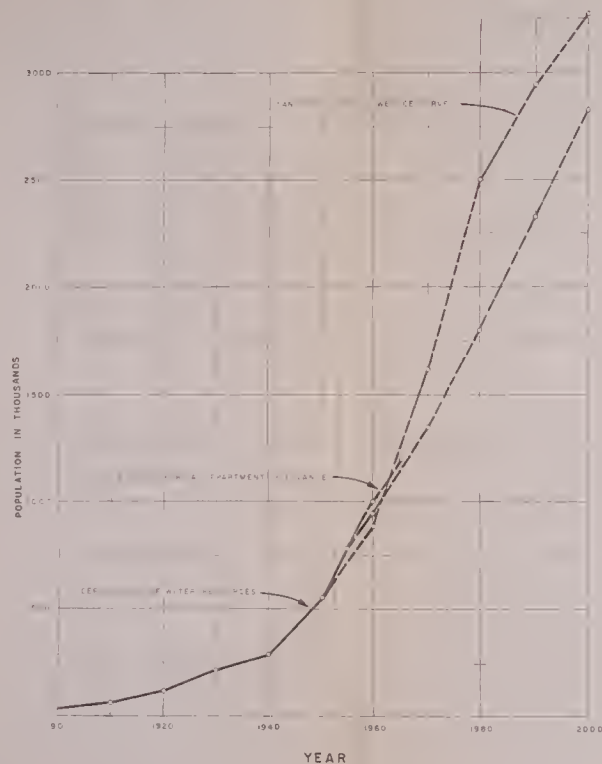
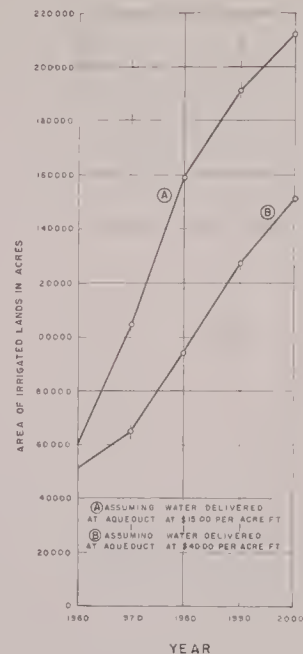
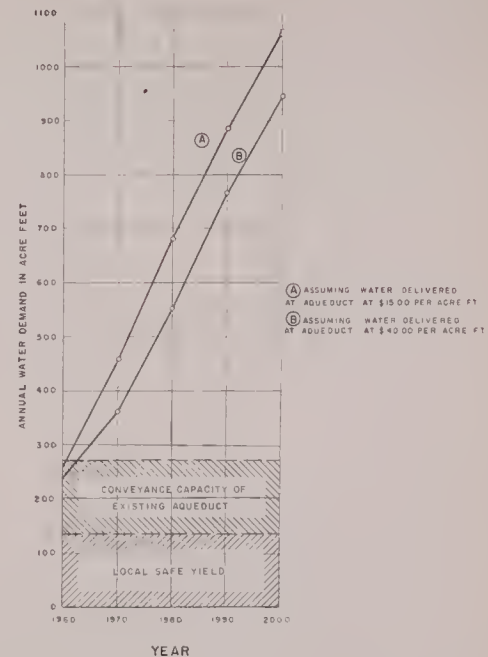
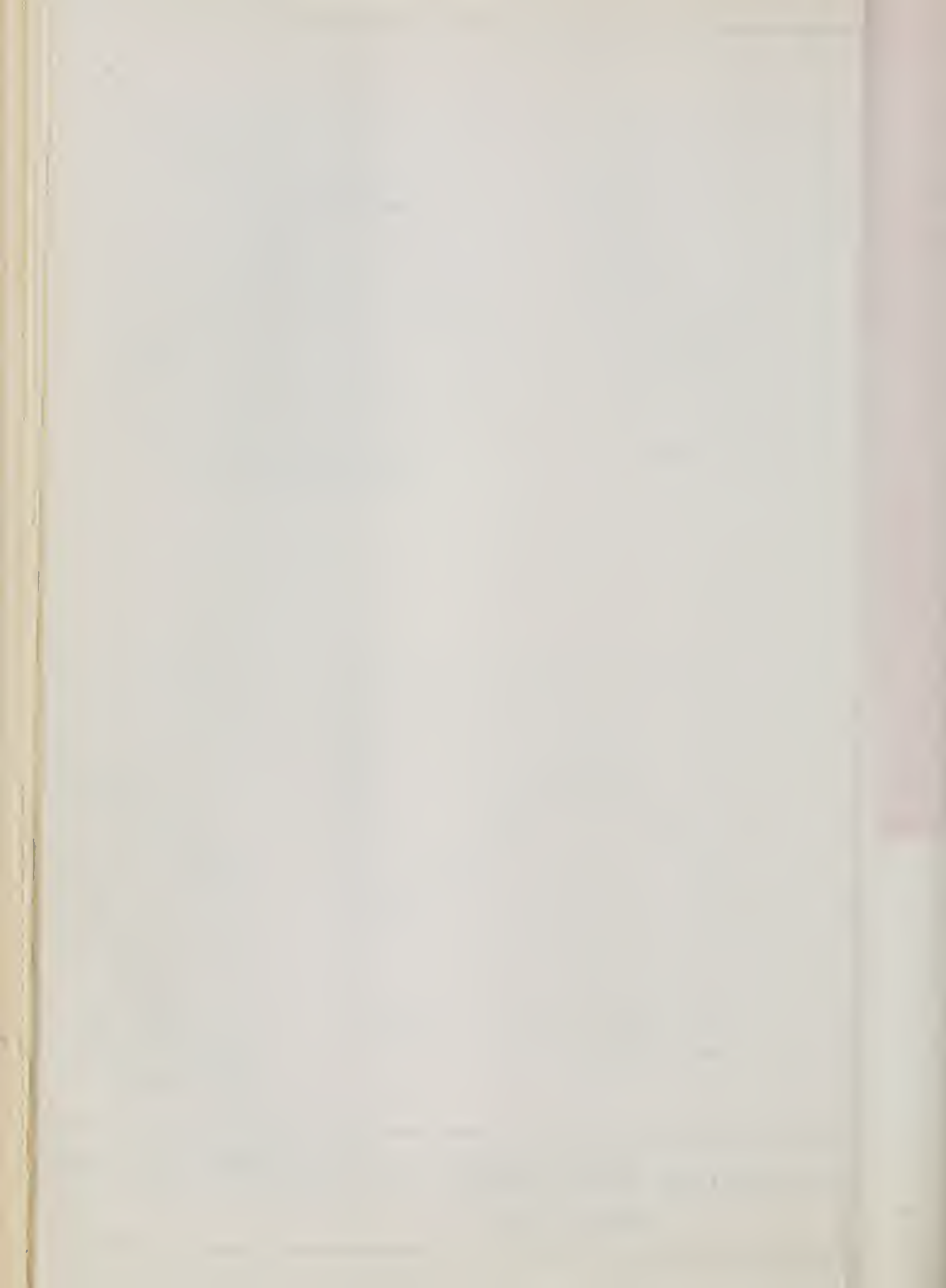
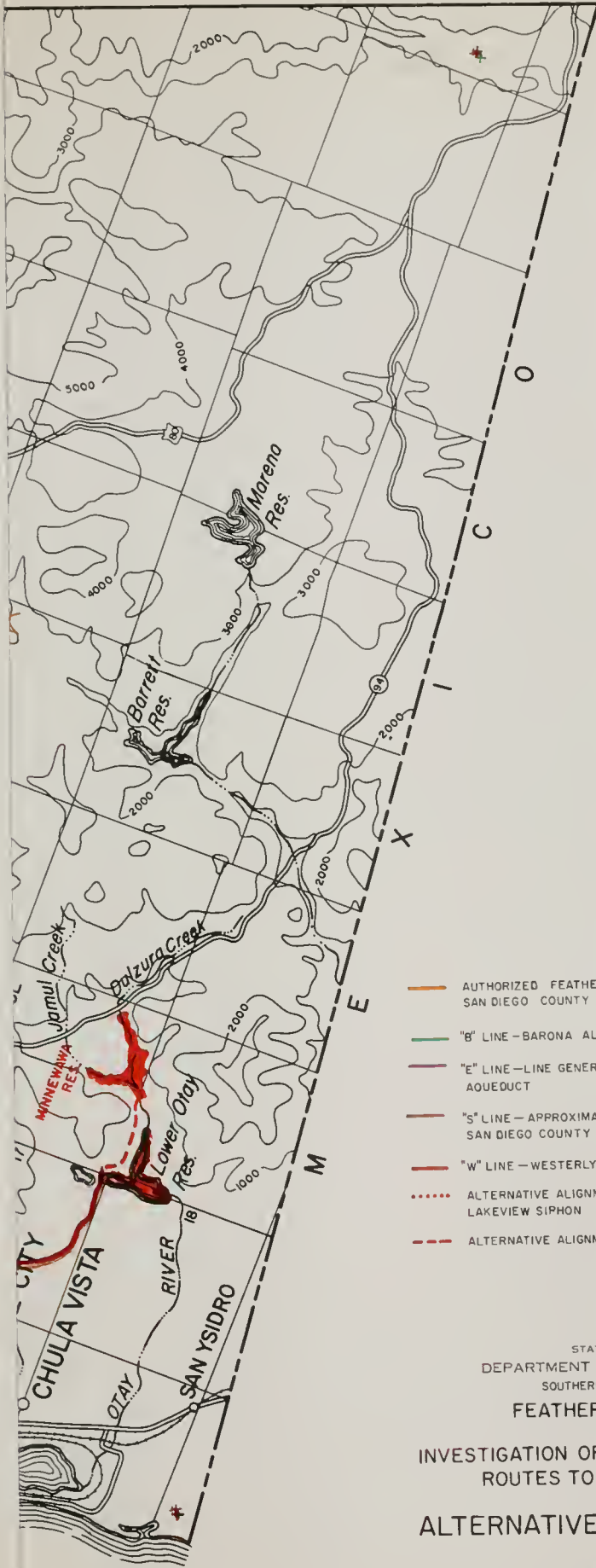
HISTORICAL AND ESTIMATED FUTURE POPULATION OF
SAN DIEGO COUNTY

PLATE 6

ESTIMATED FUTURE AREAS OF
IRRIGATED LANDS IN THE
SAN DIEGO AQUEDUCT SERVICE AREAESTIMATED FUTURE DEMAND FOR WATER
IN THE SAN DIEGO AQUEDUCT SERVICE AREA

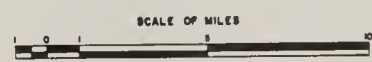




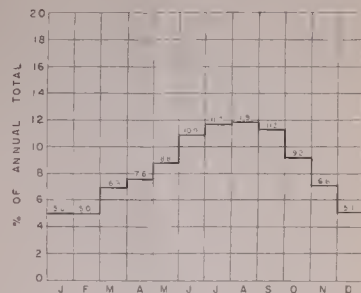
LEGEND

- AUTHORIZED FEATHER RIVER PROJECT AQUEDUCT ROUTE TO SAN DIEGO COUNTY
- "B" LINE - BARONA ALIGNMENT
- "E" LINE - LINE GENERALLY PARALLEL TO EXISTING SAN DIEGO AQUEDUCT
- "S" LINE - APPROXIMATE ALIGNMENT INVESTIGATED BY SAN DIEGO COUNTY WATER AUTHORITY
- "W" LINE - WESTERLY ALIGNMENT
- ALTERNATIVE ALIGNMENT LEADING FROM EAST END OF LAKEVIEW SIPHON
- - - ALTERNATIVE ALIGNMENT TO TERMINUS IN MINNEWAWA RESERVOIR

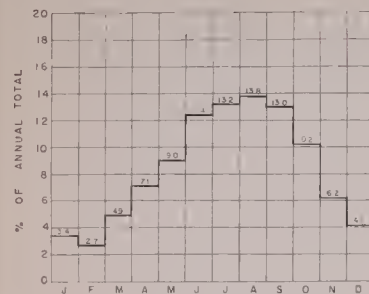
STATE OF CALIFORNIA
 DEPARTMENT OF WATER RESOURCES
 SOUTHERN CALIFORNIA DISTRICT
 FEATHER RIVER PROJECT
 INVESTIGATION OF ALTERNATIVE AQUEDUCT
 ROUTES TO SAN DIEGO COUNTY
 ALTERNATIVE AQUEDUCT ROUTES
 1957



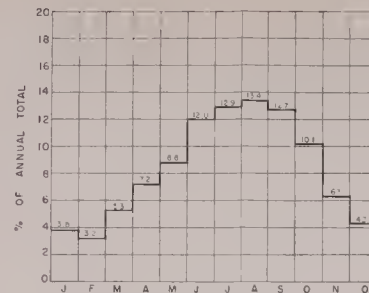




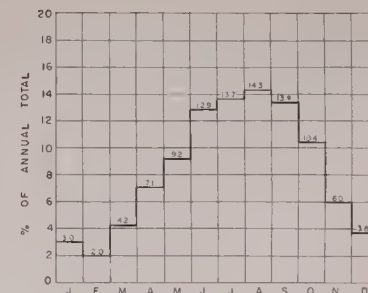
CARLSBAD M.W.D., RANCHO EL CAJON AREA,
NEAR OCEANSIDE AREA, EAST OF DEL MAR AREA



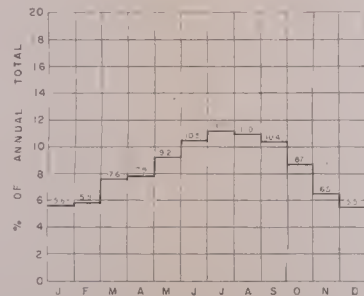
RINCON DEL DIABLO M.W.D., RINCON AREA,
EAST OF SAN DIEGUITO AREA



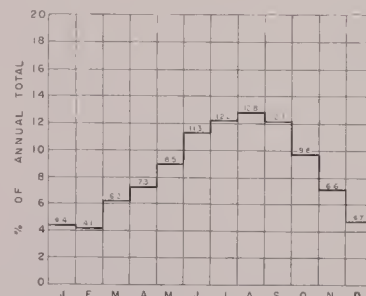
BUENA COLORADO MUNICIPAL WATER DISTRICT



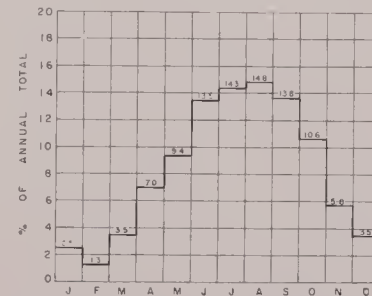
RAMONA M.W.C., MURRIETA AREA,
WINCHESTER SOUTH AREA,
AGUA TIBIA AREA



CITY OF SAN DIEGO, CITY OF ESCCONDIDO, CITY OF
OCEANSIDE, HELIX IRRIG. DIST., NATIONAL CITY,
SOUTH BAY IRRIG. DIST., U.S. GOV'T CAMPS
PENDLETON & ELLIOTT, OTAY M.W.D., RIO SAN DIEGO
M.W.D., IMPERIAL AREA & NEAR MIRAMAR AREA

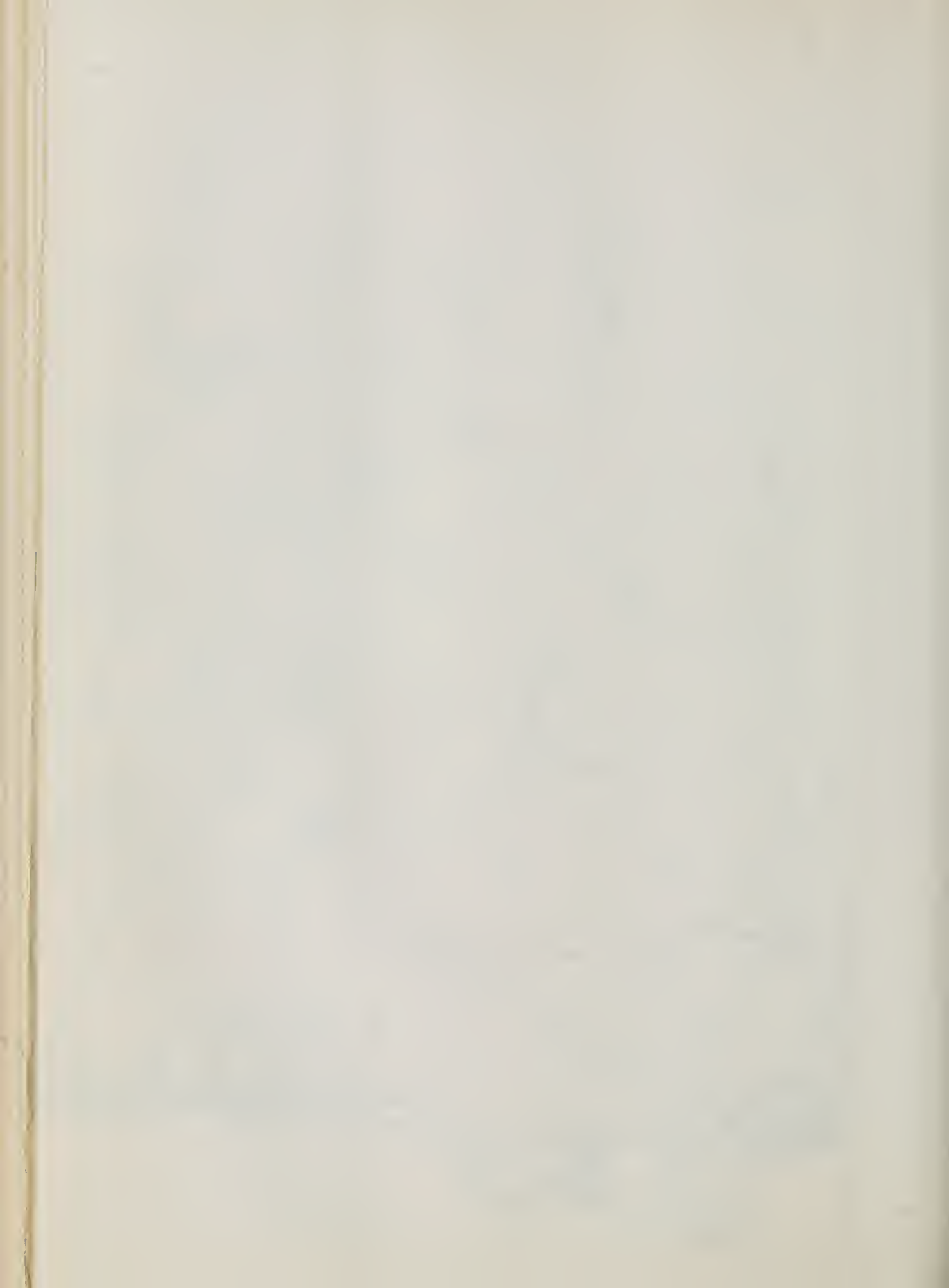


SAN DIEGUITO IRRIG. DIST., FALLBROOK R.U.D.,
SANTA FE IRRIG. DIST., POWAY M.W.D.,
EL CAPITAN AREA, SAN VICENTE AREA



RAINBOW M.W.D., VALLEY CENTER M.W.D.,
PAUMA VALLEY AREA, LOWER PAUMA VALLEY
AREA, NORTH OF SANTA FE AREA,
SOUTH OF LAKE HODGES AREA

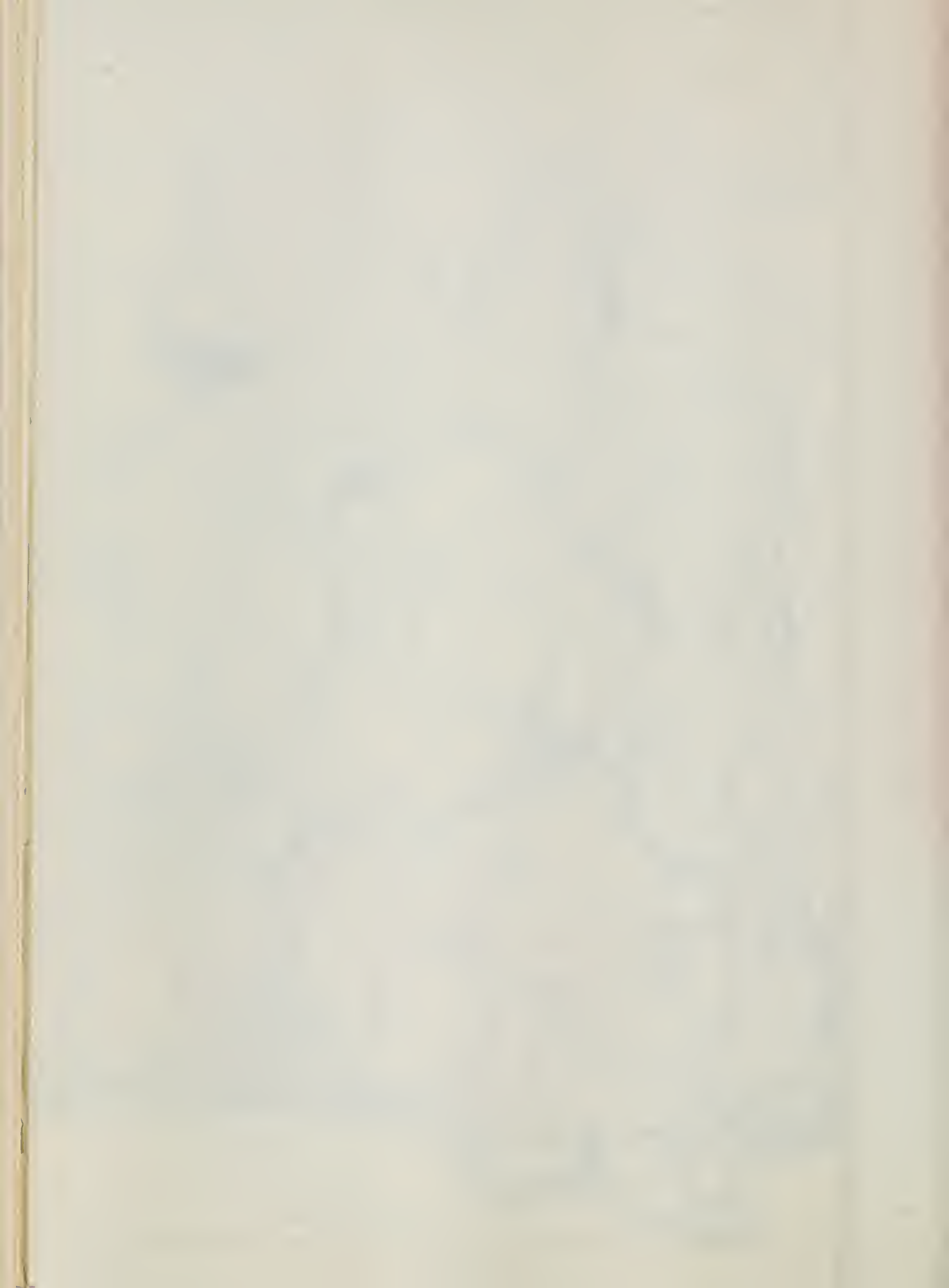
ESTIMATED MONTHLY DISTRIBUTION OF DEMAND FOR WATER IN PER CENT OF ANNUAL DEMAND
IN YEAR 2000

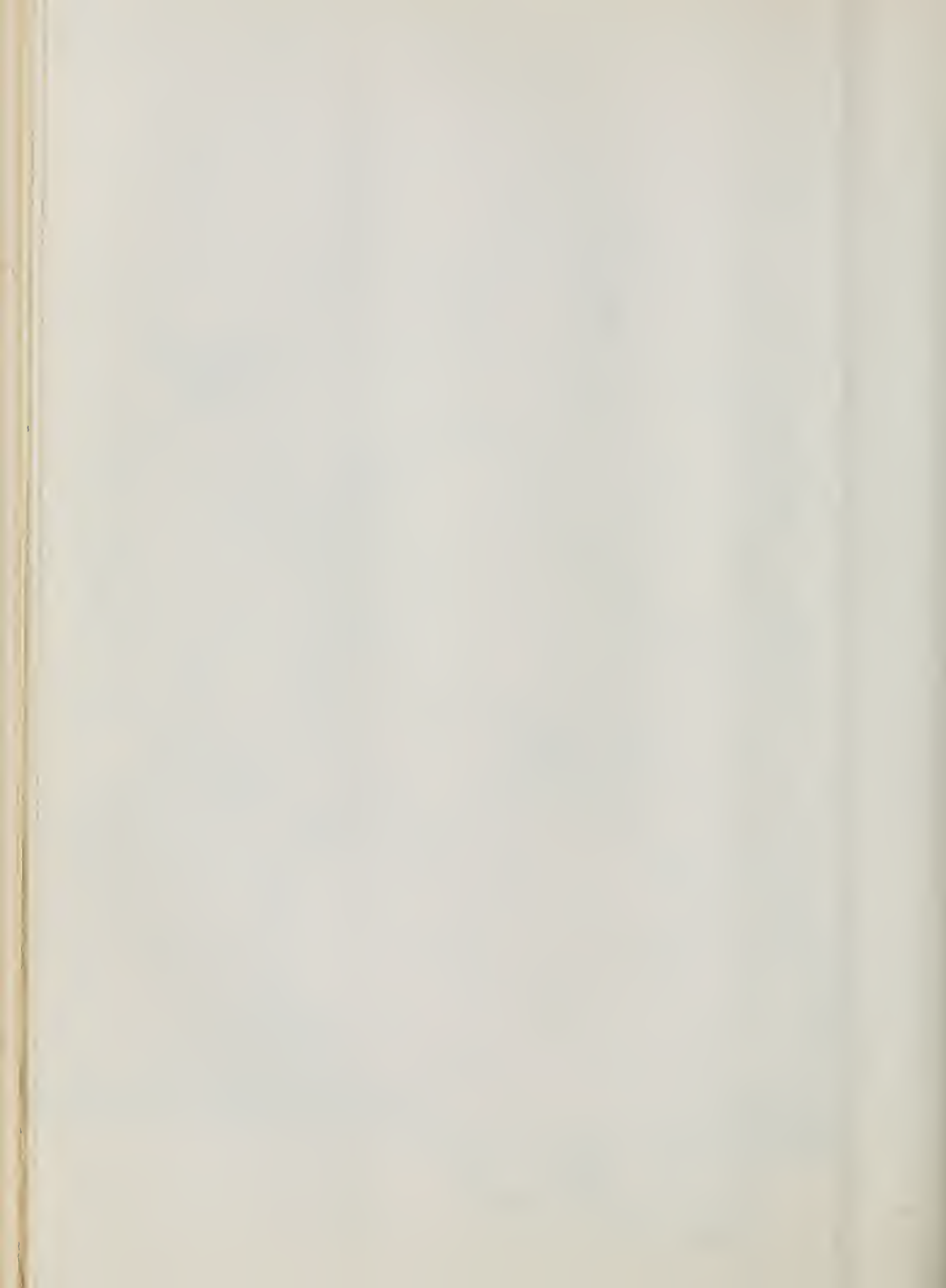


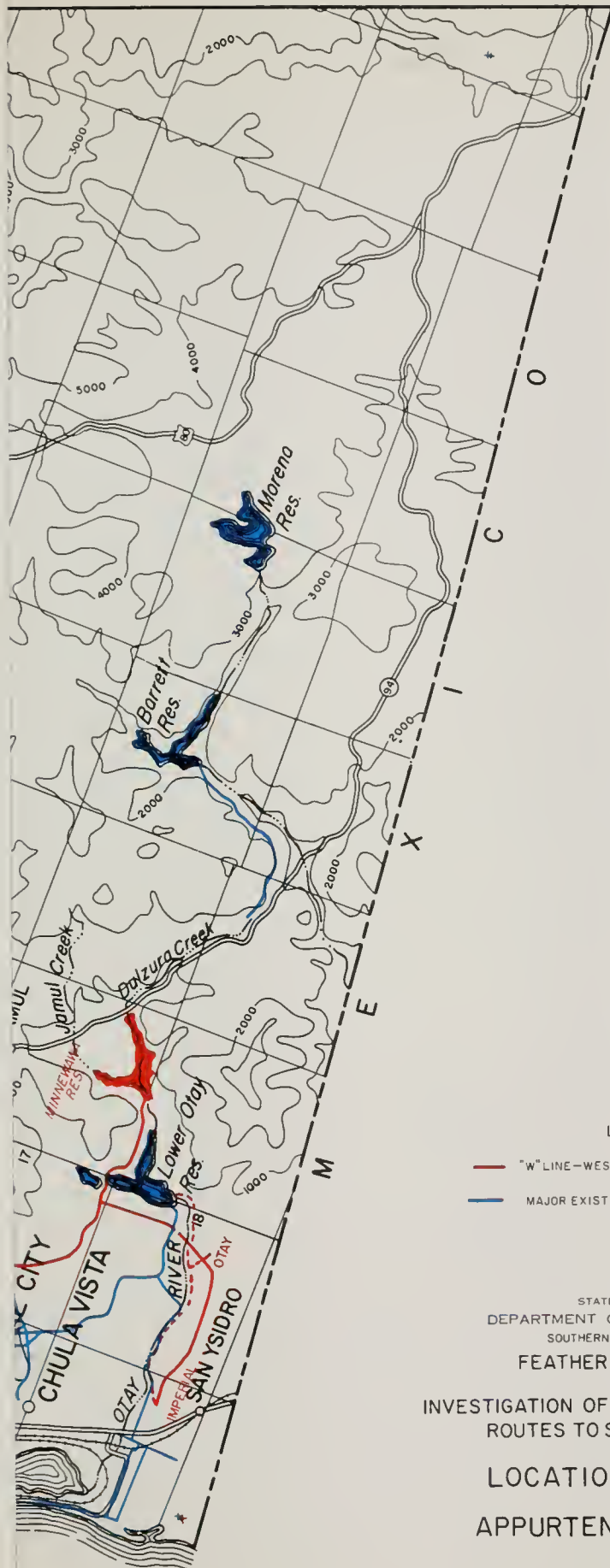
"E" LINE—LINE GENERALLY PARALLEL TO EXISTING SAN DIEGO
AQUEDUCT

MAJOR EXISTING WATER SUPPLY FACILITIES

SCALE OF MILES





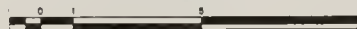


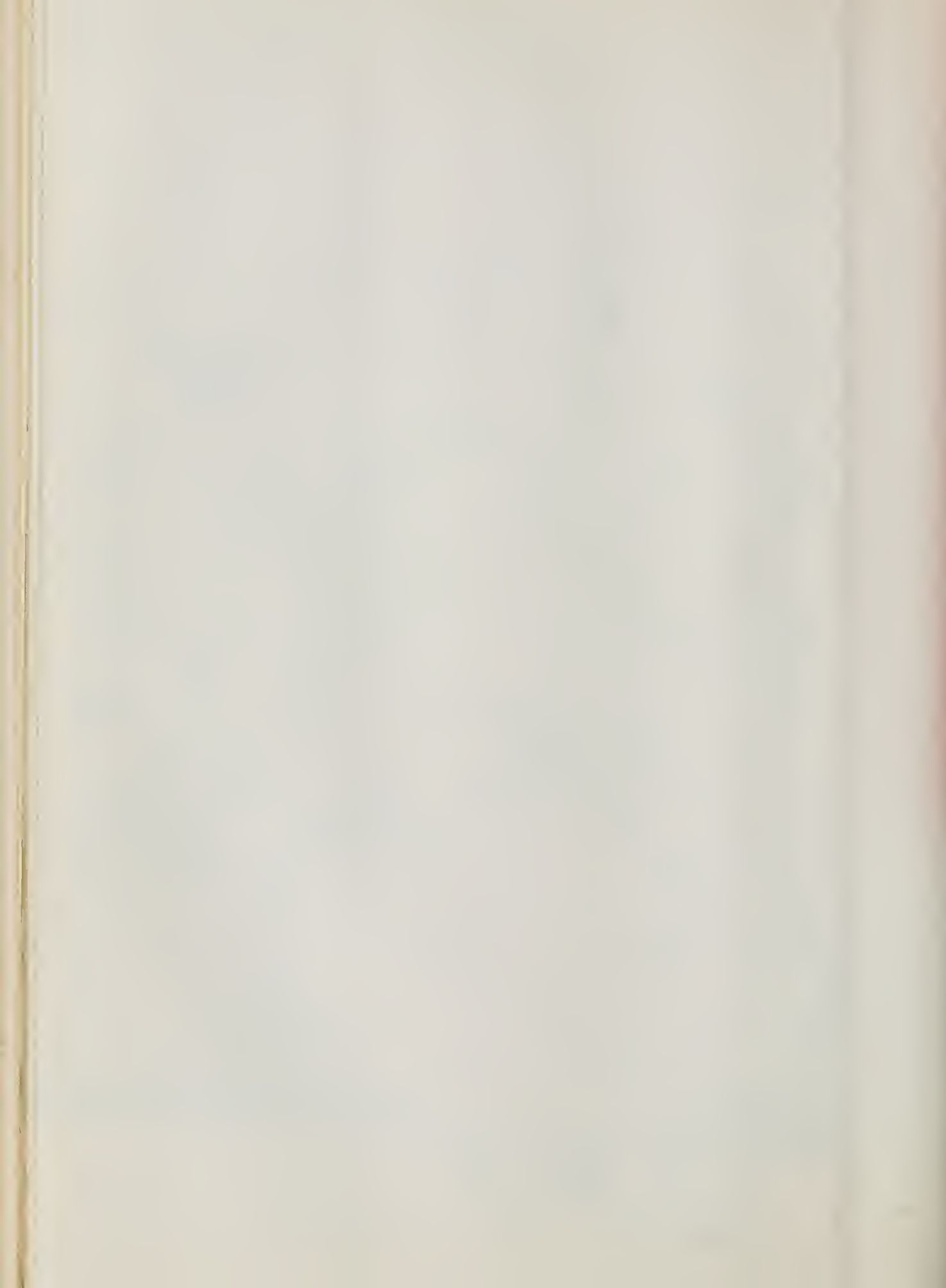
LEGEND

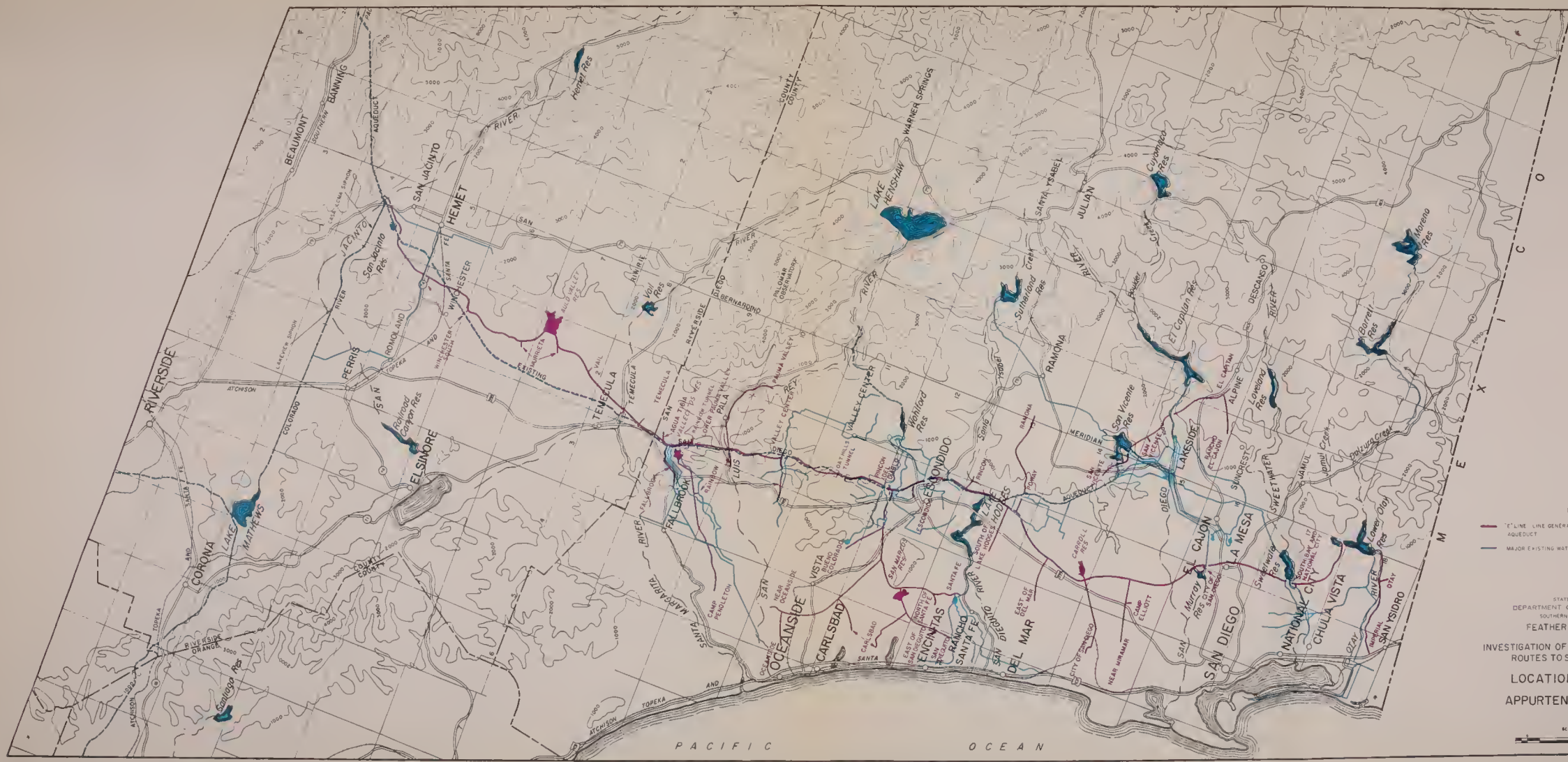
- "W" LINE—WESTERLY ALIGNMENT
- MAJOR EXISTING WATER SUPPLY FACILITIES

STATE OF CALIFORNIA
 DEPARTMENT OF WATER RESOURCES
 SOUTHERN CALIFORNIA DISTRICT
 FEATHER RIVER PROJECT
 INVESTIGATION OF ALTERNATIVE AQUEDUCT
 ROUTES TO SAN DIEGO COUNTY
 LOCATION OF "W" LINE
 AND
 APPURTENANT FACILITIES
 1957

SCALE OF MILES





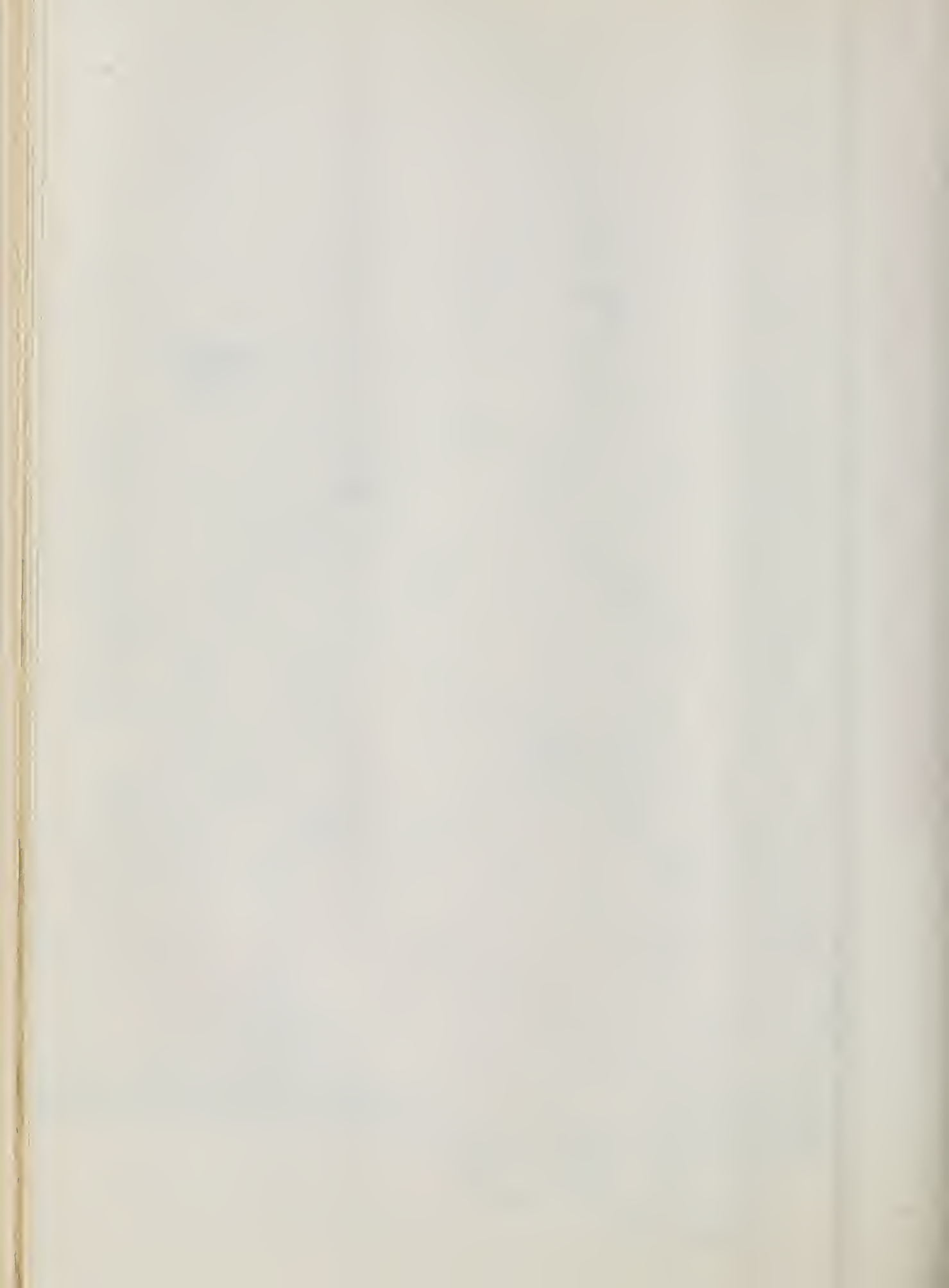


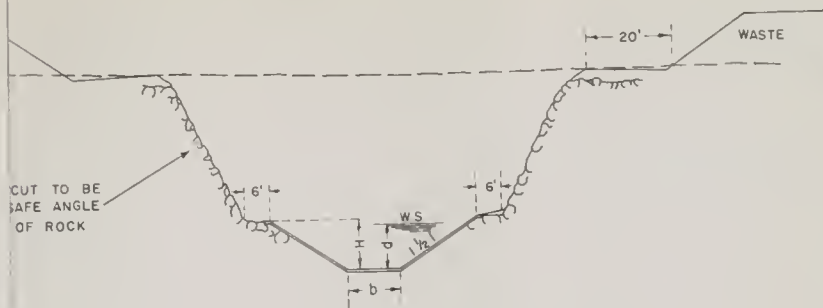
LEGEND

- "E" LINE GENERALLY PARALLEL TO EXISTING SAN DIEGO AQUEDUCT
- MAJOR EXISTING WATER SUPPLY FACILITIES

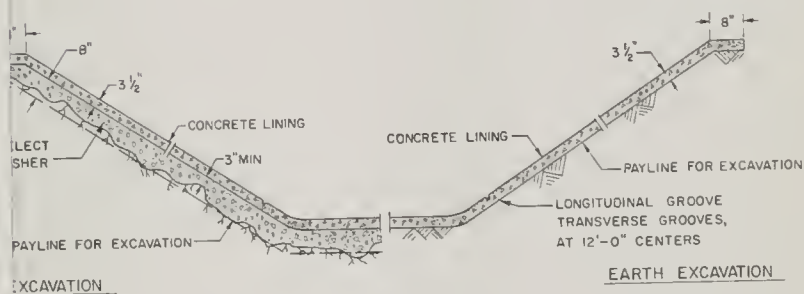
STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT
FEATHER RIVER PROJECT
INVESTIGATION OF ALTERNATIVE AQUEDUCT ROUTES TO SAN DIEGO COUNTY
LOCATION OF "E" LINE
AND APPURTENANT FACILITIES
1957

SCALE OF MILES

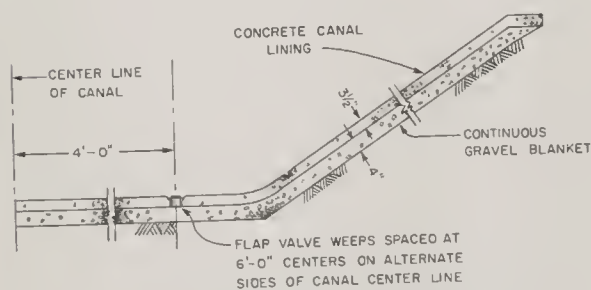




TYPICAL SECTION THROUGH
DEEP ROCK CUT

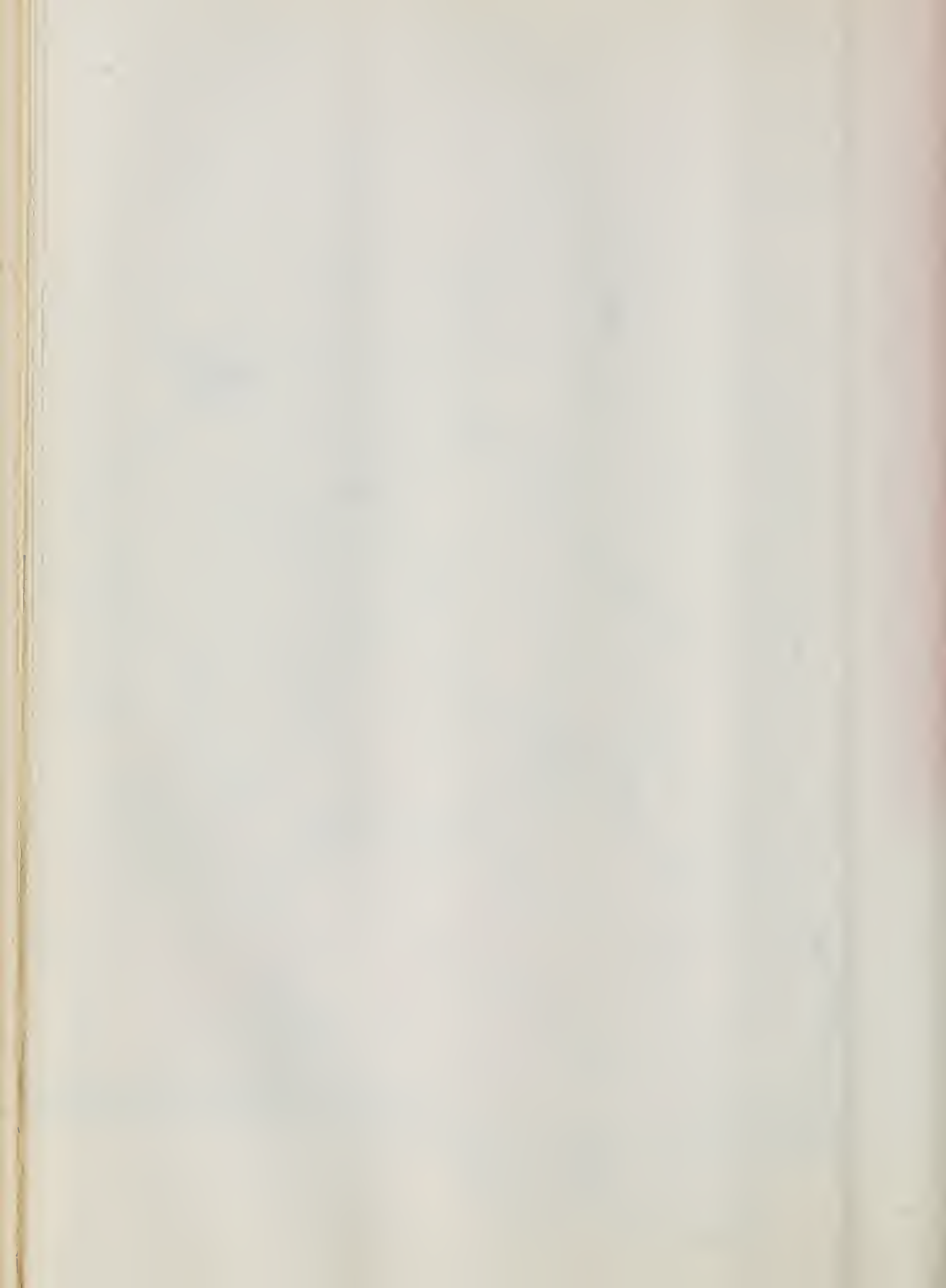


LINING DETAIL



TYPICAL UNDERDRAIN

STATE OF CALIFORNIA DEPARTMENT OF WATER RESOURCES SOUTHERN CALIFORNIA DISTRICT			
PROJECT FEATHER RIVER		DATE 1/26/47	
FEATURE SAN DIEGO AQUEDUCT		APPROVED <i>Max B. [Signature]</i> District Engineer	
TYPICAL CANAL SECTIONS			
DESIGNED E.E.J.	SUBMITTED <i>K. B. [Signature]</i> Checked <i>[Signature]</i>	APPROVED <i>[Signature]</i> District Engineer	
DRAWN EEA B RPB	APPROVAL RECOMMENDED <i>[Signature]</i> District Engineer	DRAWING NO.	FILE NO.
CHECKED <i>[Signature]</i>			
DATE	DESCRIPTION	SUB	APPD.





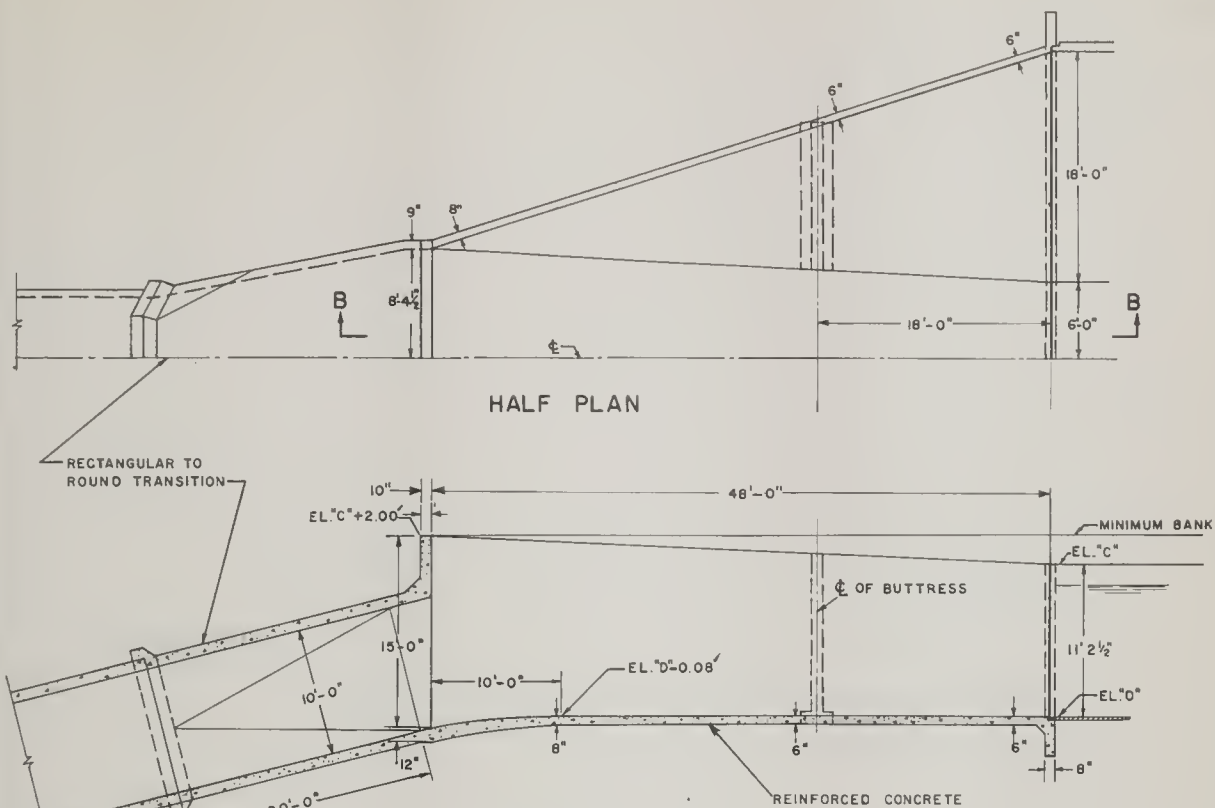
LEGEND

— "S" LINE - APPROXIMATE ALIGNMENT INVESTIGATED BY
SAN DIEGO COUNTY WATER AUTHORITY

— MAJOR EXISTING WATER SUPPLY FACILITIES

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT
FEATHER RIVER PROJECT
INVESTIGATION OF ALTERNATIVE AQUEOUCT
ROUTES TO SAN DIEGO COUNTY
LOCATION OF "S" LINE
AND
APPURTENANT FACILITIES
1957

SCALE OF MILES



1" I.D. PRECAST OR
MONOLITHIC REINFORCED
CONCRETE PIPE.

SECTION B-B

TYPICAL OUTLET TRANSITION

(CONNECTION TO CONCRETE PIPE TYPE SIPHON SHOWN)

SCALE: 0 1 2 3 4 5 6 FT.

HYDRAULIC PROPERTIES OF CONCRETE PIPE SIPHON

$Q = 884 \text{ c.f.s.}$
 $d = 10 \text{ ft.}$
 $A = 78.54 \text{ Sq. ft.}$
 $V = 11.26 \text{ ft./sec.}$

$n = .0115$
 $r = 2.50$
 $s = .00224$

STATE OF CALIFORNIA DEPARTMENT OF WATER RESOURCES SOUTHERN CALIFORNIA DISTRICT					
PROJECT FEATHER RIVER					
FEATURE SAN DIEGO AQUEDUCT TYPICAL SIPHONS STA. 0+00 TO STA. 1586+75					
DESIGNED E.E.N.	SUBMITTED K.B. Wilson		APPROVED DATE 1/16/57		
DRAWN LSG	RECOMMENDED J. H. H. H.		District Engineer		
CHECKED R. H. H.	APPROVAL RECOMMENDED R. H. H.		DRAWING NO.		FILE NO.
REV	DATE	DESCRIPTION	SUB	APPD	

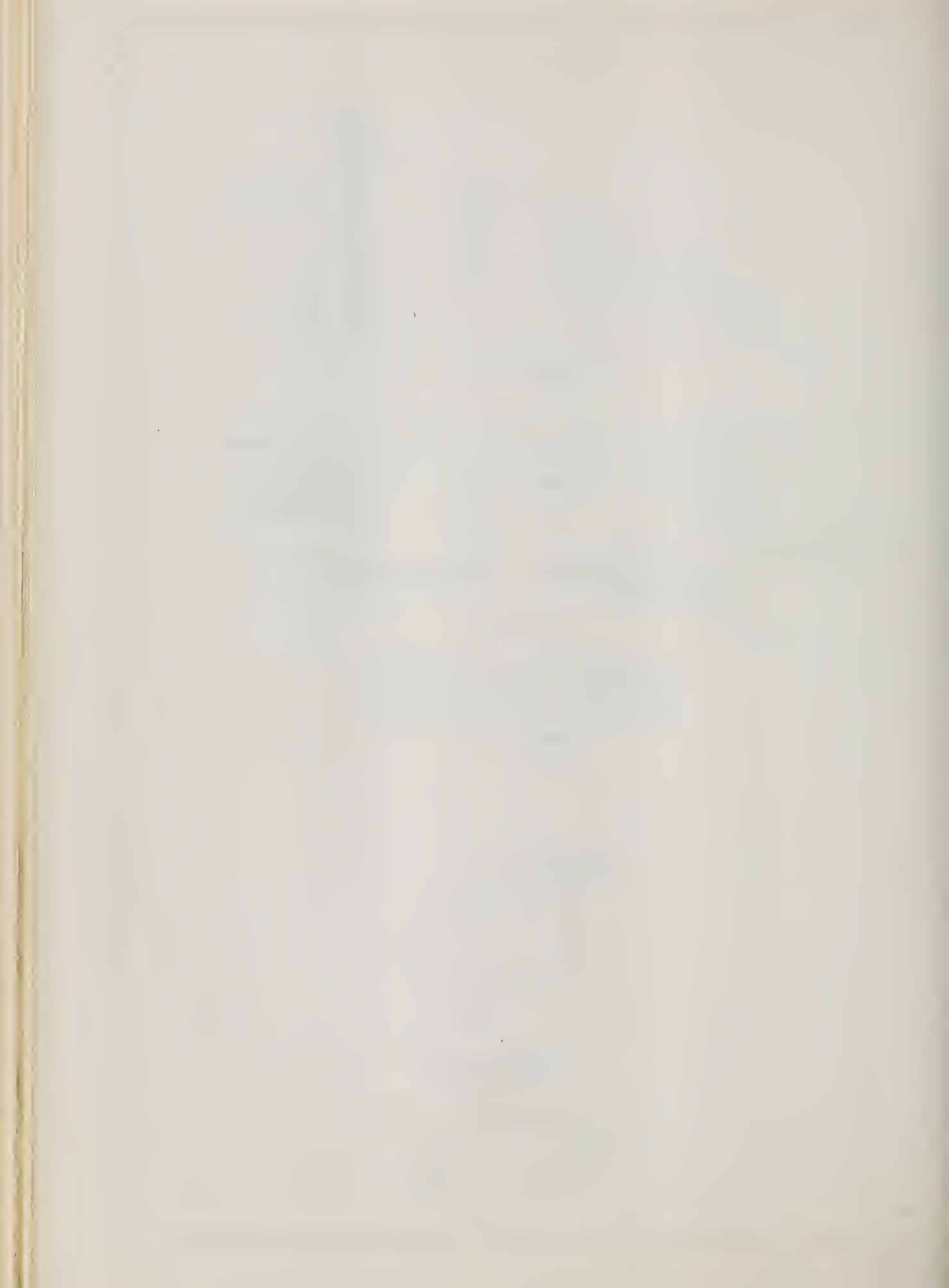


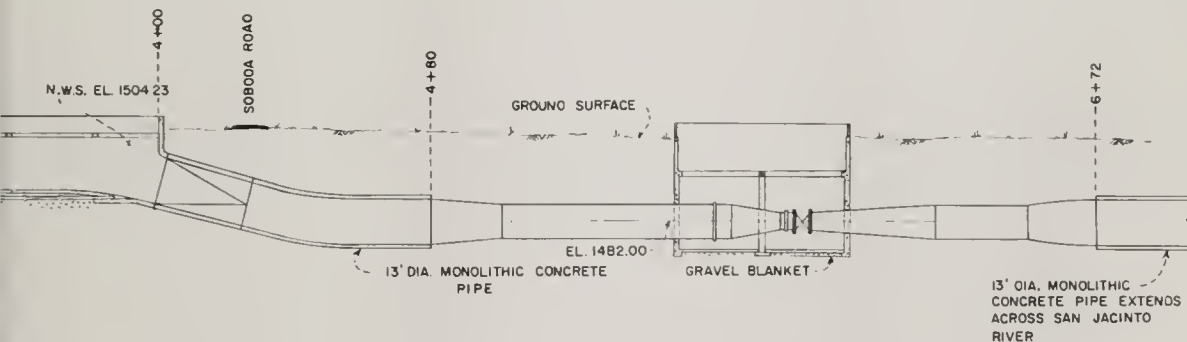
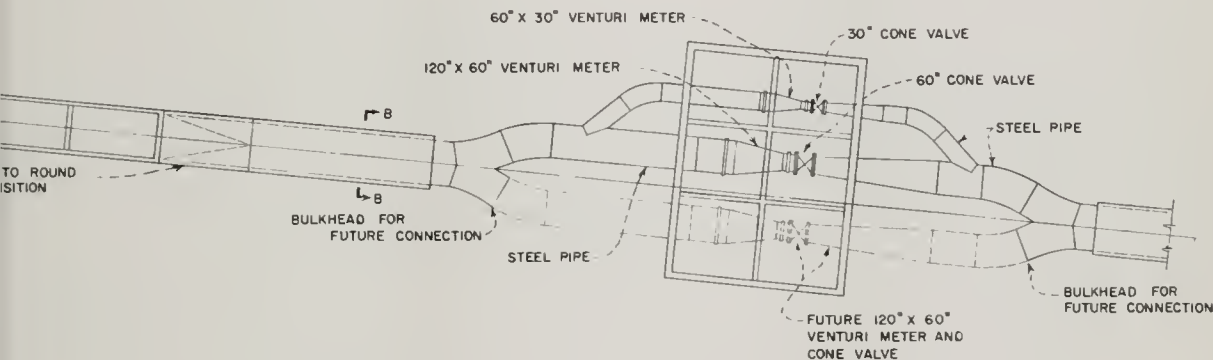
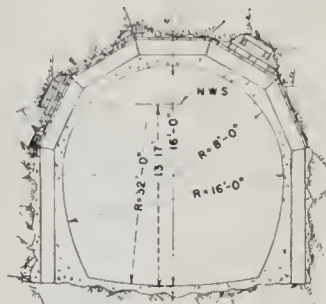
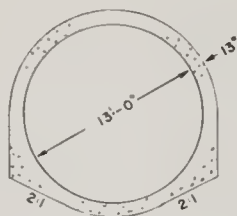
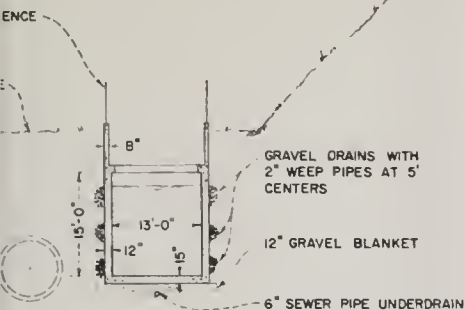
LEGEND

- "W" LINE—WESTERLY ALIGNMENT
- MAJOR EXISTING WATER SUPPLY FACILITIES

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT
FEATHER RIVER PROJECT
INVESTIGATION OF ALTERNATIVE AQUEDUCT
ROUTES TO SAN DIEGO COUNTY
LOCATION OF "W" LINE
AND
APPURTENANT FACILITIES
1957

SCALE OF MILES



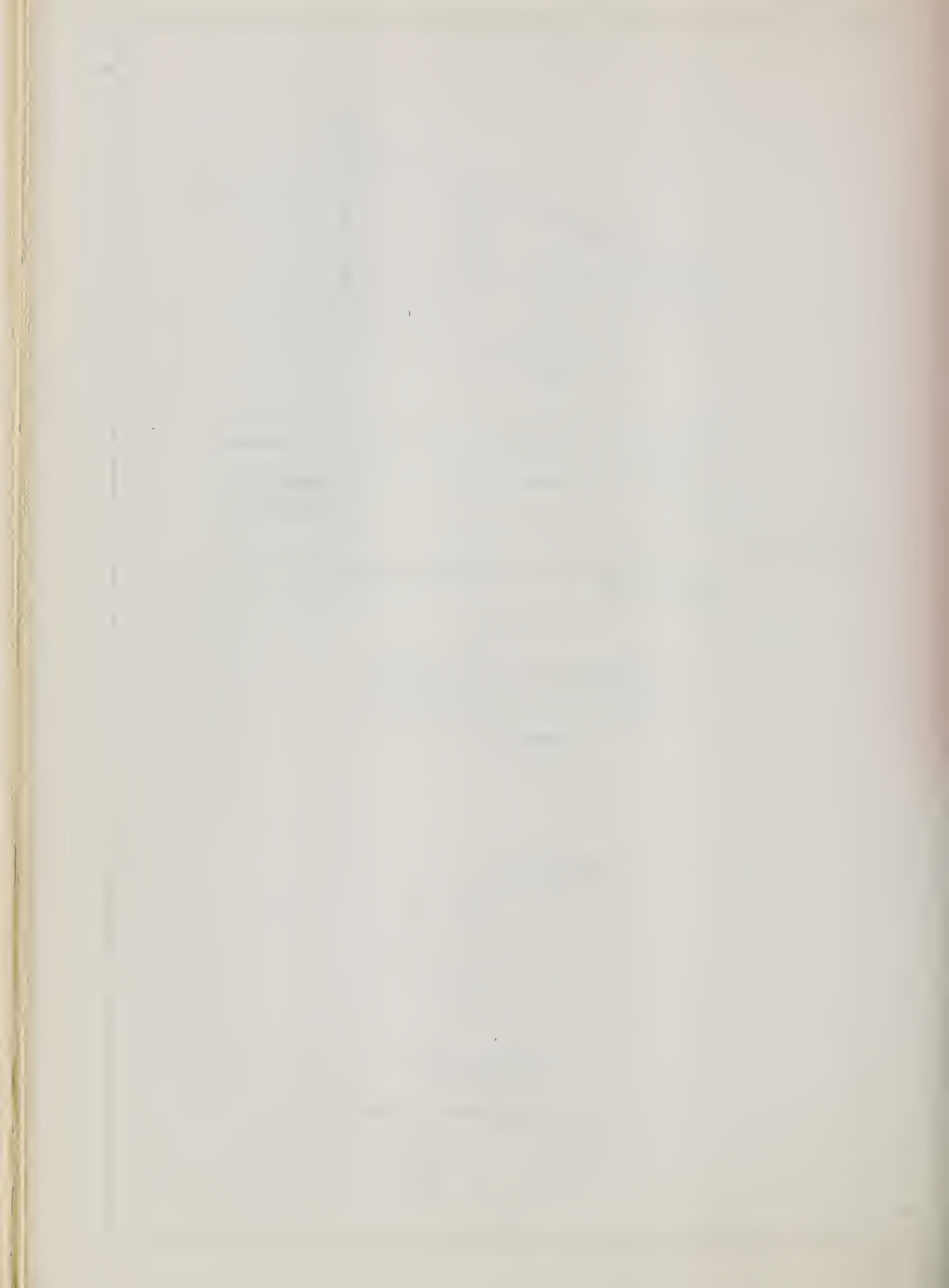


SECTION

SCALE OF FEET
0 10 20 40

REV	DATE	DESCRIPTION	SUB	APP'D

STATE OF CALIFORNIA DEPARTMENT OF WATER RESOURCES SOUTHERN CALIFORNIA DISTRICT			
PROJECT FEATHER RIVER			
FEATURE SAN DIEGO AQUEDUCT DIVERSION AND METERING STRUCTURES			
DESIGNED: F.J.L.	SUBMITTED: R. B. L. 2/2/57	APPROVED: DATE 2/4/57	
DRAWN: CMV	RECOMMENDED: J. M. L. 2/2/57	Max. Borkman District Engineer	
CHECKED: E.E.J.	APPROVAL RECOMMENDED: R. M. L. 2/2/57	DRAWING NO.	FILE NO.



6 CHAIN LINK FENCE
IN POPULATED AREAS,
A STAND BARRIED
WIRE ELSEWHERE

25 MBS

25 MBS

16.00 m

1:1

SAFE ANGLE FOR TYPE OF ROCK

CONTRACTED EXHIBIMENT

A hand-drawn sketch of a road cross-section. It shows a horizontal line representing the road surface, with a label "4' GRAVEL SURFACING" below it. To the left of this line, there is a sloped area labeled "20'" with a dimension line indicating the width. The sketch is drawn on a piece of paper with a grid pattern.

The diagram illustrates a trench cross-section with various layers and dimensions. Key features include:

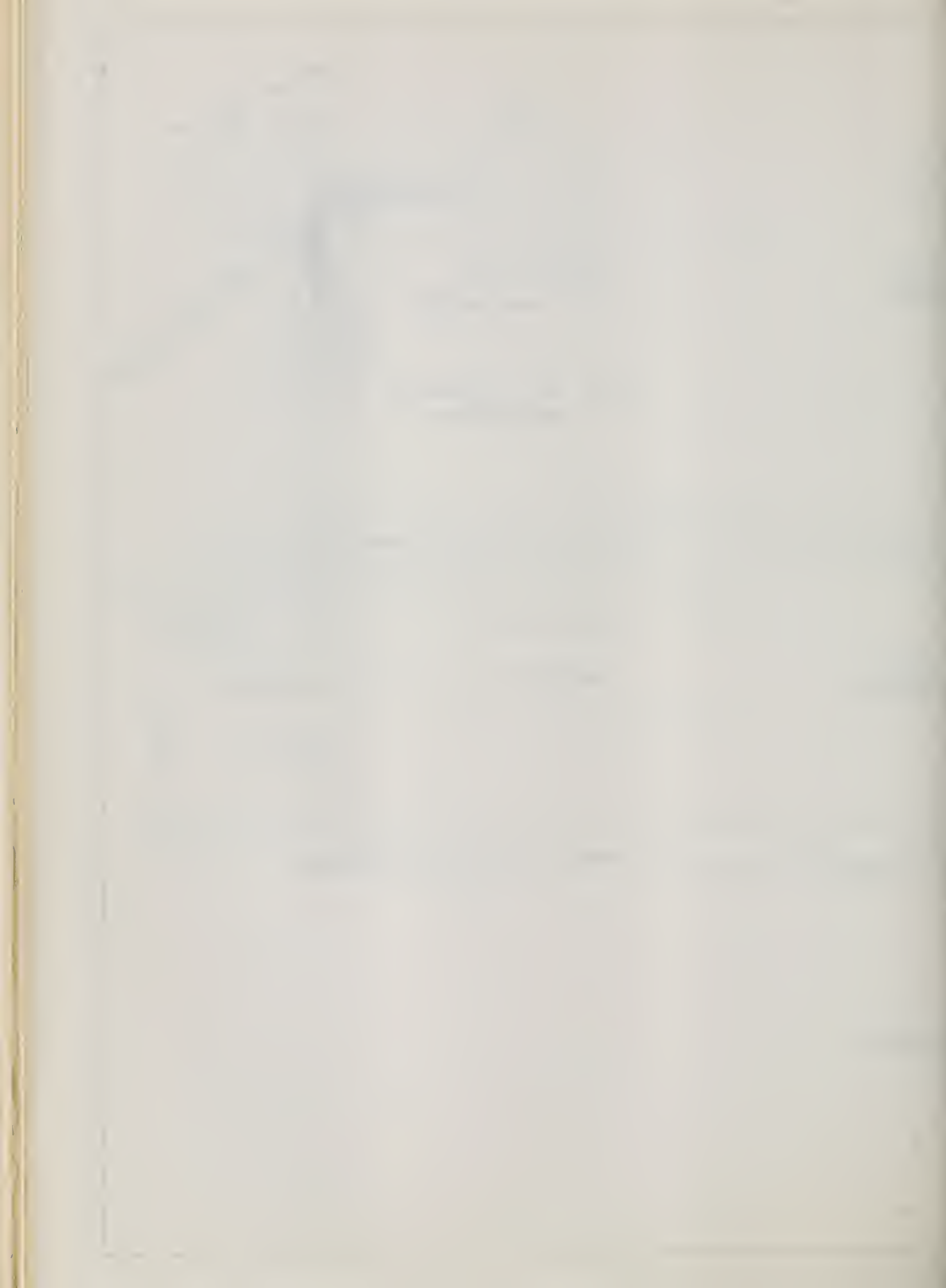
- Backfill with select material or crusher run base:** The material filling the trench above the lining.
- Concrete lining:** The structural layer lining the trench walls and bottom.
- Payline for excavation:** The boundary line for the excavation work.
- Longitudinal groove transverse grooves at 12'-0" centers:** Grooves cut into the concrete lining for reinforcement or drainage.
- Dimensions:**
 - Top width: 8' 0"
 - Bottom width: 8' 0"
 - Side slope: 3 1/2 : 1
 - Bottom width: 12' 0"

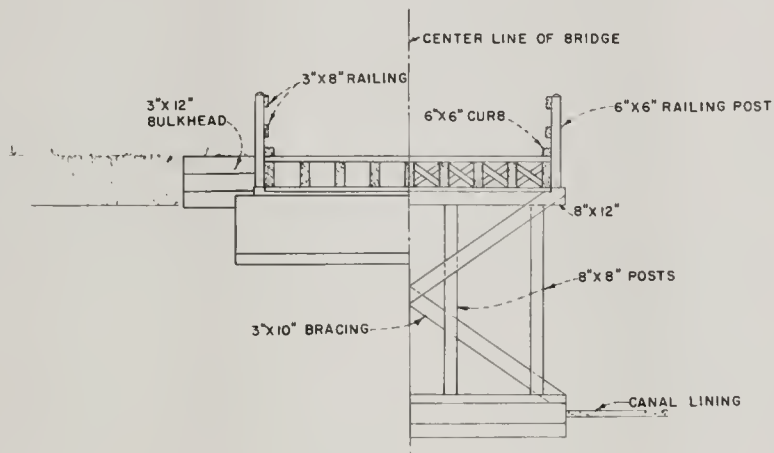
The diagram illustrates a cross-section of a concrete canal lining. A horizontal line represents the center line of the canal, with a dimension of 6'-0" shown. The lining is shown as a sloped structure with a concrete canal lining and a continuous gravel blanket. A flap valve weep is shown spaced at 6'-0" centers on alternate sides of the canal center line. The diagram also shows a concrete canal lining and a continuous gravel blanket.

b	d	H	A	V	Q	v	n	S
12.0	10.49	12.00	290.94	3.44	1000	5.84	0.14	0.0001
12.0	9.87	11.40	264.57	3.34	884	5.56	0.14	0.0001

b	d	H	A	V	Q	v	n	S
12.0	10.49	12.00	290.94	3.44	1000	5.84	0.14	0.0001
12.0	9.87	11.40	264.57	3.34	884	5.56	0.14	0.0001

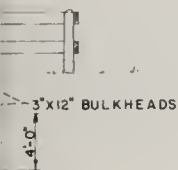
STATE OF CALIFORNIA DEPARTMENT OF WATER RESOURCES SOUTHERN CALIFORNIA DISTRICT			
PROJECT FEATHER RIVER			
FEATURE SAN DIEGO AQUADUCT			
TYPICAL CANAL SECTIONS DESIGNED BY <u>W. J. GIBBETTS</u> DATE <u>12-26-50</u> DRAWN BY <u>W. J. GIBBETTS</u> SCALE <u>1" = 20'</u> CHECKED BY <u>W. J. GIBBETTS</u> DATE <u>1-1-51</u> APPROVED BY <u>W. J. GIBBETTS</u> DATE <u>1-1-51</u>			





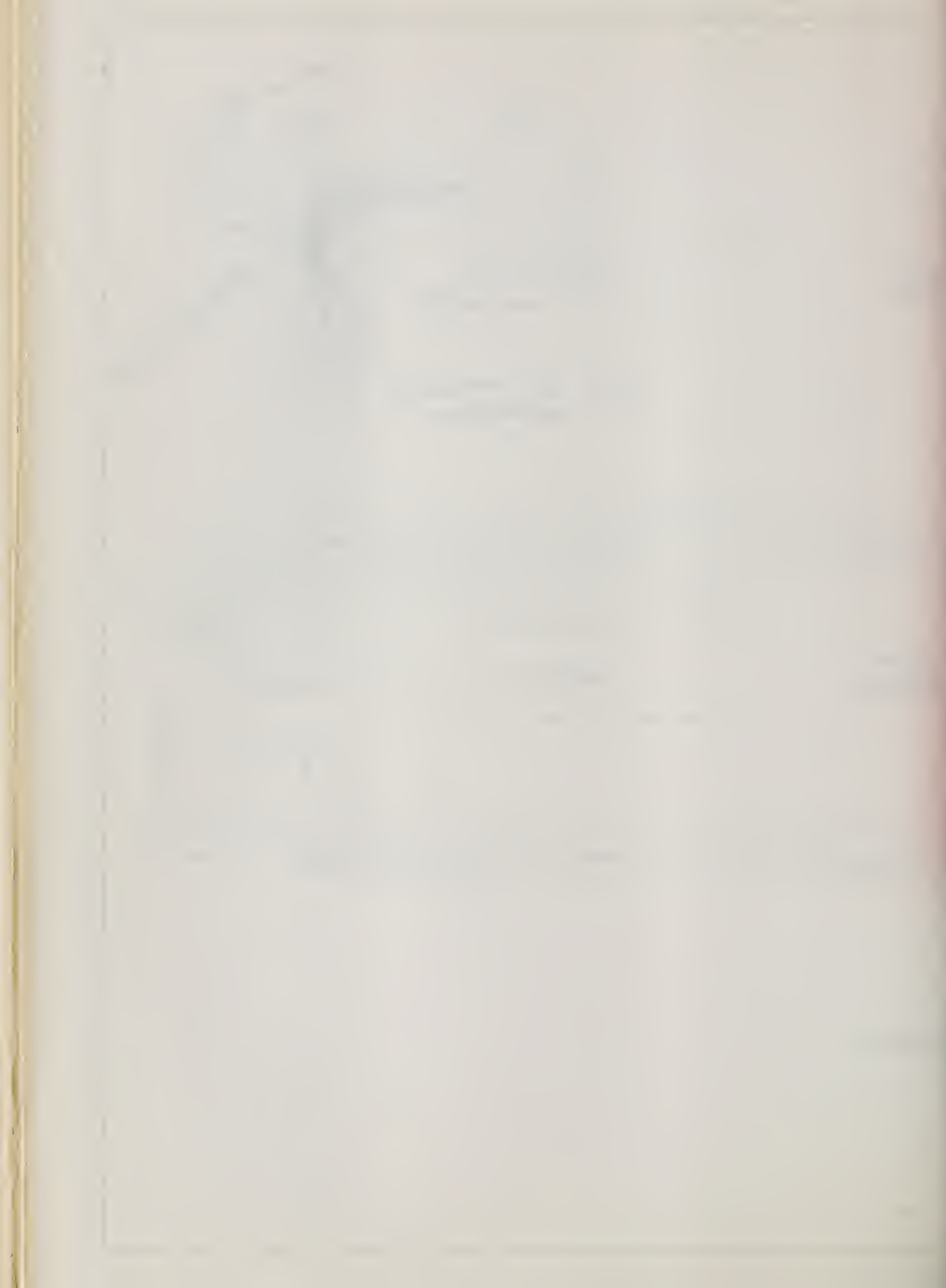
SECTION B-B

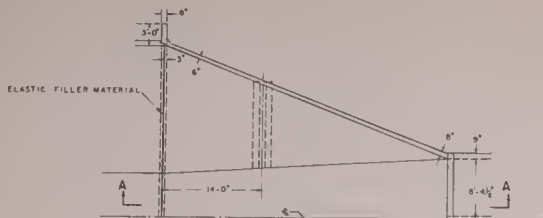
SCALE OF FEET
0 1 2 3 4 5



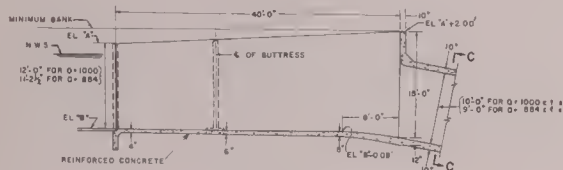
STATE OF CALIFORNIA DEPARTMENT OF WATER RESOURCES SOUTHERN CALIFORNIA DISTRICT			
PROJECT FEATHER RIVER			
FEATURE SAN DIEGO AQUEDUCT TYPICAL FARM AND PRIVATE ROAD BRIDGES			
DESIGNED ECS	SUBMITTED K.B. Wilber Planning	APPROVED DATE 2/4/47 Max Berkman District Engineer	
DRAWN C.M.V.	RECOMMENDED R.M. Edmonston Principal Hydraulic Engineer		
CHECKED JH	APPROVAL RECOMMENDED R.M. Edmonston	DRAWING NO	FILE NO

REV	DATE	DESCRIPTION	SUB	APPD





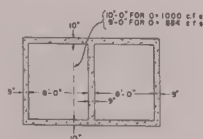
HALF PLAN



SECTION A-A

 TYPICAL INLET TRANSITION
(CONNECTION TO BOX TYPE SIPHON SHOWN)

SCALE 1" = 10'-0"

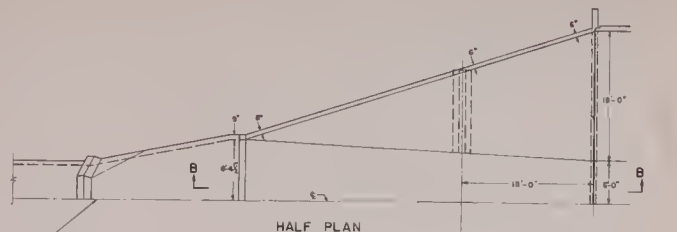


SECTION C-C

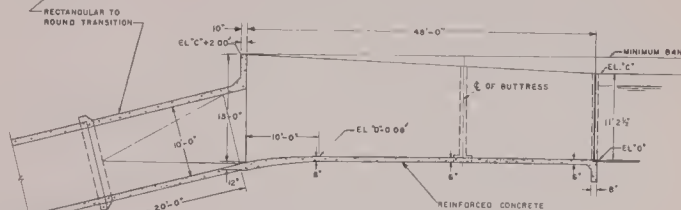
 TYPICAL SECTION OF
BOX SIPHON

HYDRAULIC PROPERTIES OF BOX SIPHON

D = 1000 cfs	D = 884 cfs
A = 15.0 sq ft	A = 14.4 sq ft
V = 6.25 ft/sec	V = 6.78 ft/sec
n = 0.16	n = 0.14
f = 2.322	f = 2.12
s = 0.012	s = 0.0123



HALF PLAN



SECTION B-B

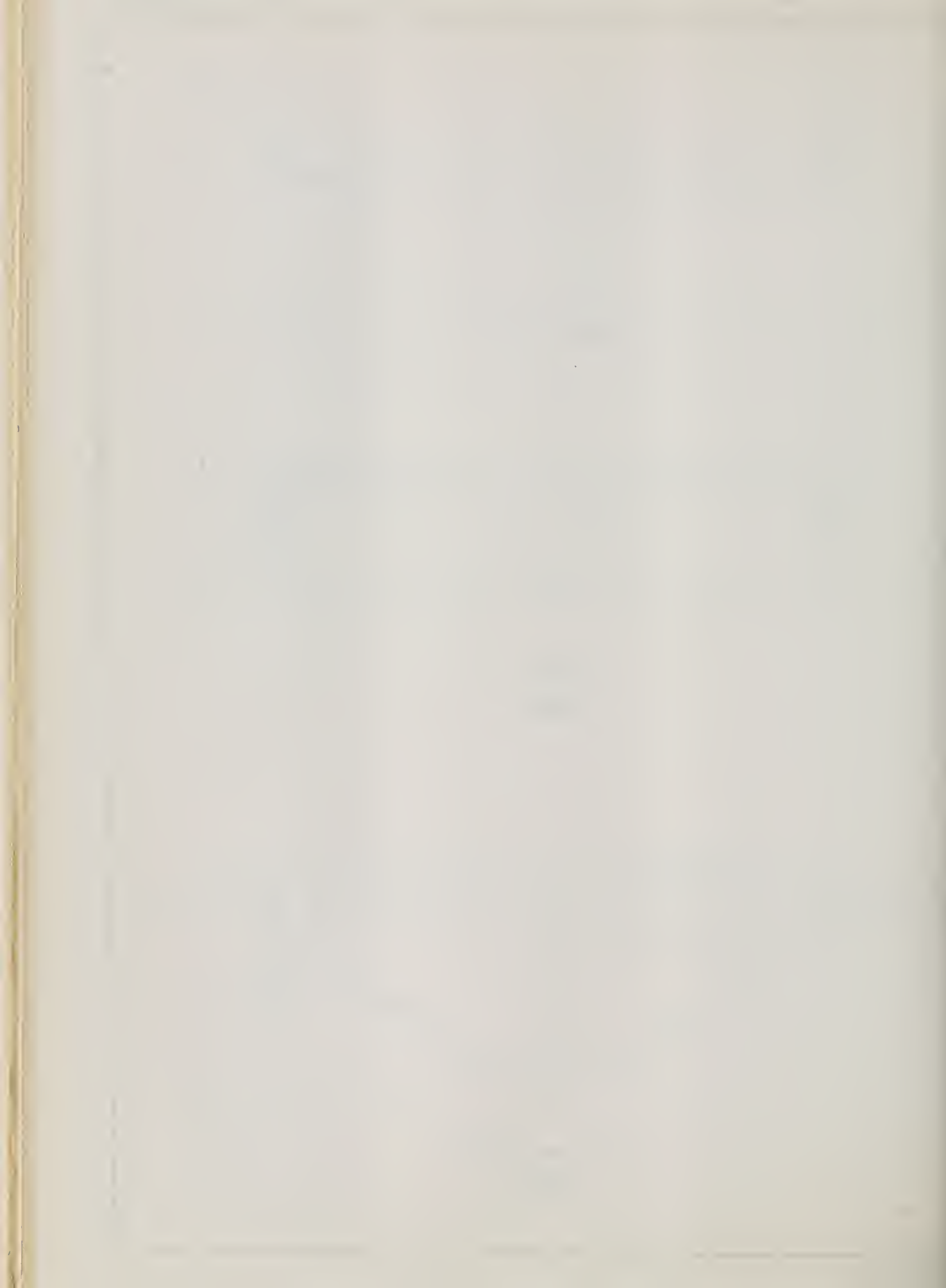
 TYPICAL OUTLET TRANSITION
(CONNECTION TO CONCRETE PIPE TYPE SIPHON SHOWN)

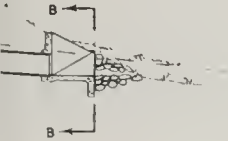
SCALE 1" = 10'-0"

HYDRAULIC PROPERTIES OF CONCRETE PIPE SIPHON

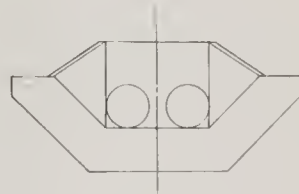
D = 884 ft	n = 0.115
A = 10.71	f = 2.50
A = 78.54 sq ft	s = 0.0224
V = 17.26 ft/sec	

STATE OF CALIFORNIA DEPARTMENT OF WATER RESOURCES SOUTHERN CALIFORNIA DISTRICT			
PROJECT FEATHER RIVER			
FEATURE SAN DIEGO AQUEDUCT TYPICAL SIPHONS STA 0+00 TO STA 1586+75			
DESIGNED C.C.V.	CHECKED S.S.G.	APPROVED J.E.H.	DATE 10-1-57
DRAWN S.S.G.		SCALE 1" = 10'-0"	
REVISIONS		APPROVED J.E.H.	
DATE 10-1-57		SCALE 1" = 10'-0"	

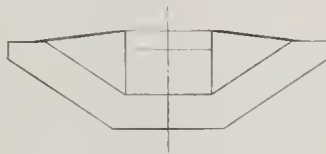




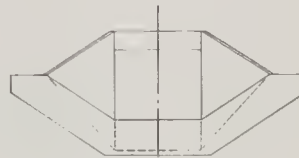
SECTION A-A



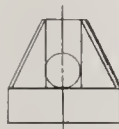
SECTION B-B



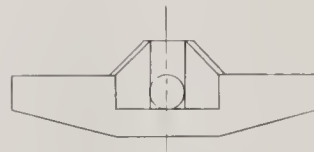
SECTION C-C



SECTION D-D



SECTION E-E

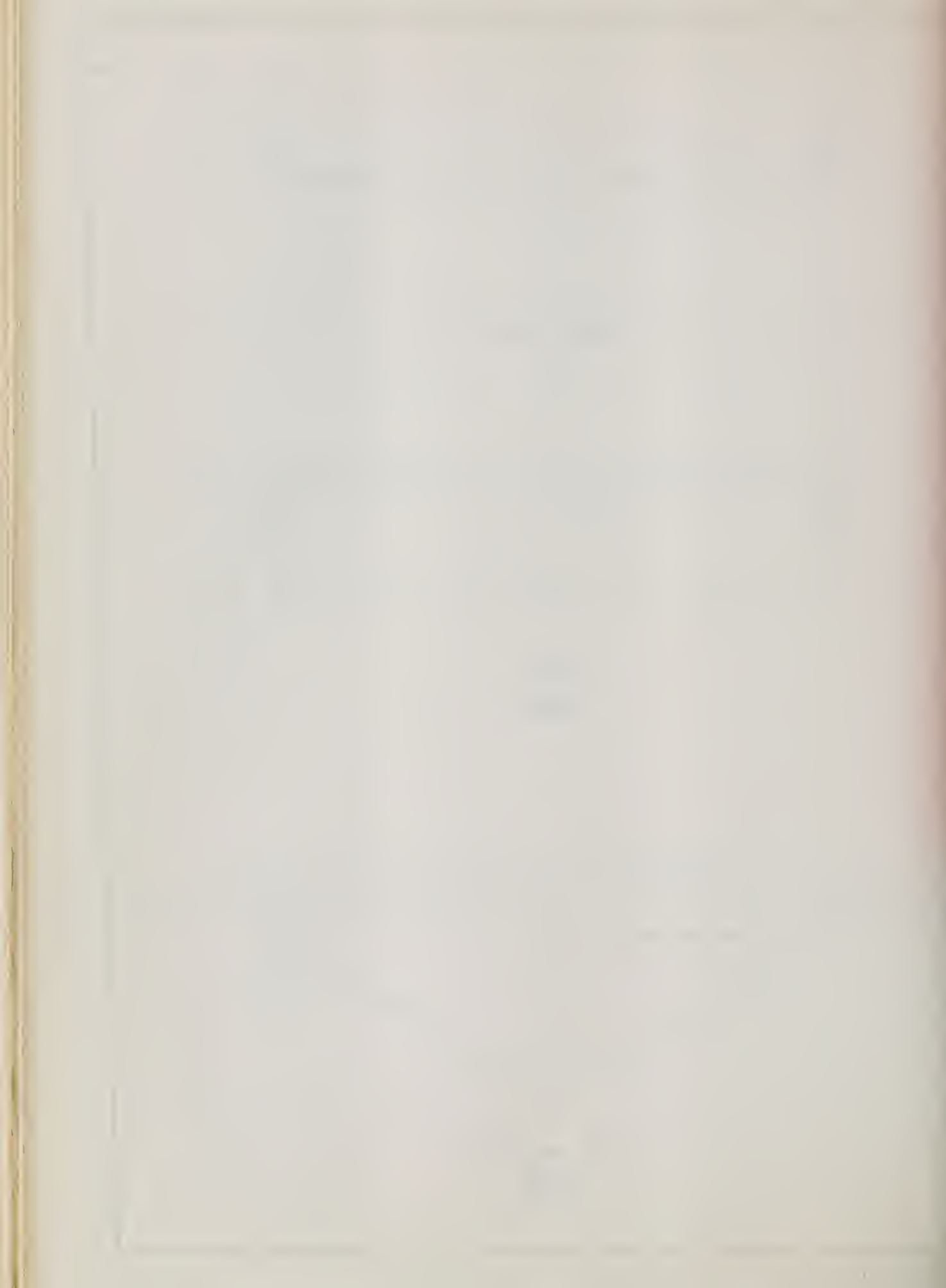


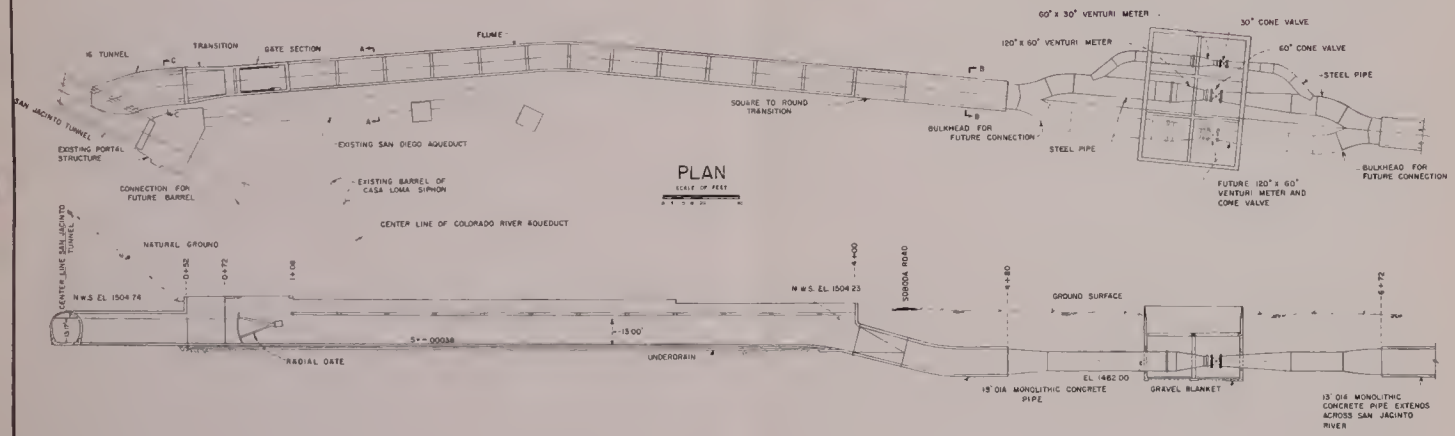
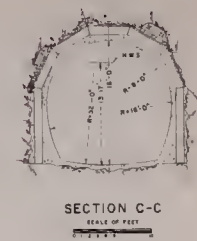
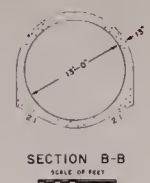
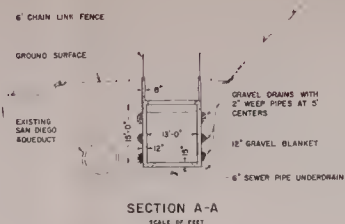
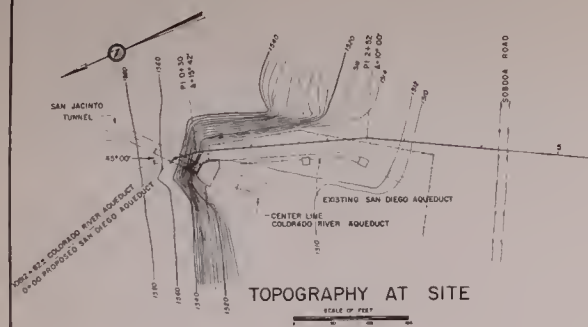
SECTION F-F

IGATION CROSSINGS
ONNECTION TO
; PIPE LINES AS REQUIRED

REV	DATE	DESCRIPTION	SUB	APP'D

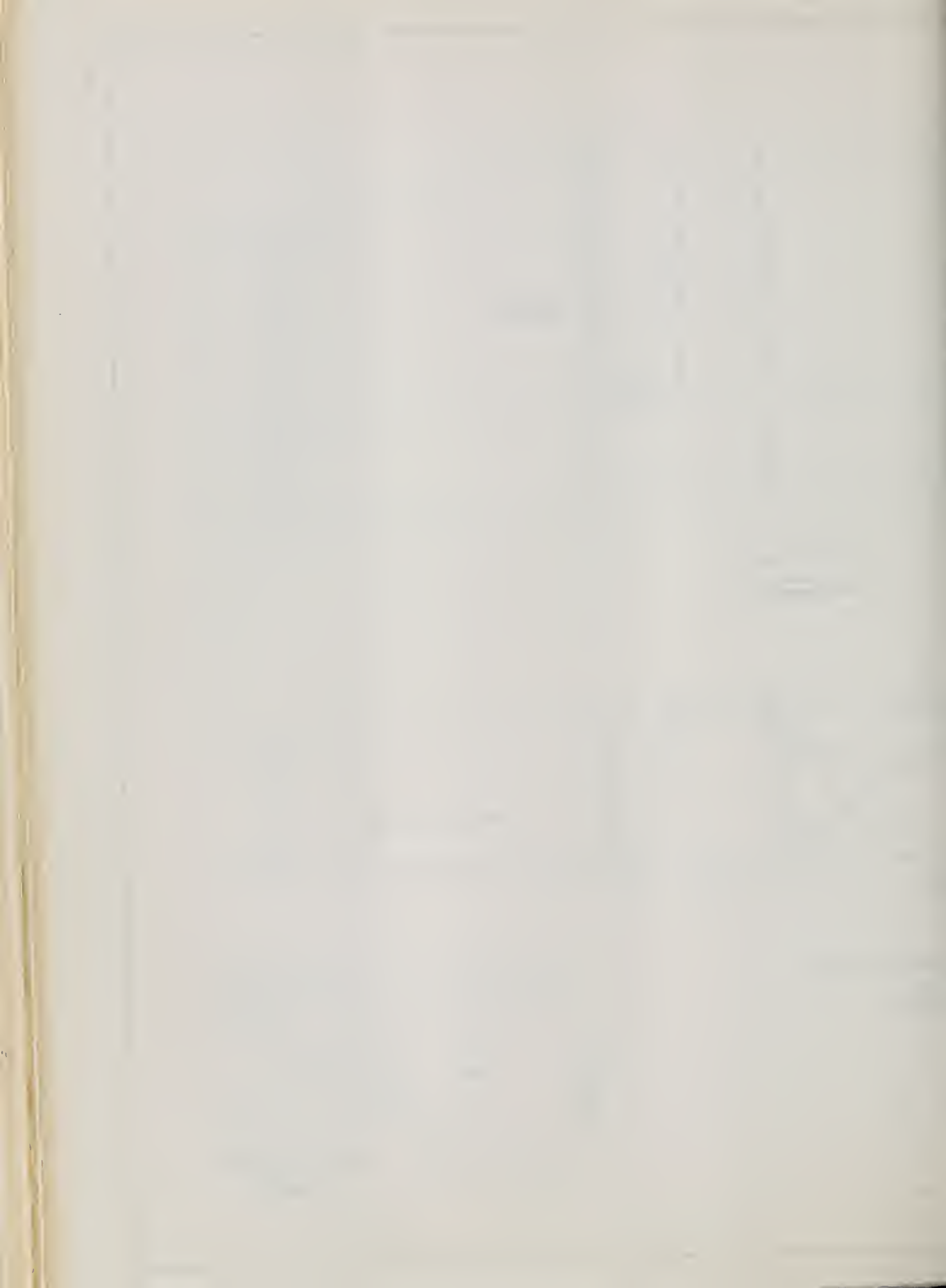
STATE OF CALIFORNIA DEPARTMENT OF WATER RESOURCES SOUTHERN CALIFORNIA DISTRICT			
PROJECT FEATHER RIVER		DATE 4/4/57	
FEATURE SAN DIEGO AQUEDUCT TYPICAL OVERCHUTES, CULVERTS AND IRRIGATION CROSSINGS			
DESIGNED EES	SUBMITTED K.S. Wilcox Principal Engineer	APPROVED Max Bookman District Engineer	
DRAWN C.M.V.	RECOMMENDED James H. Hays Principal Hydraulic Engineer	DRAWING NO.	
CHECKED 12/26	APPROVAL R.M. Edmonston Principal Hydraulic Engineer	FILE NO.	

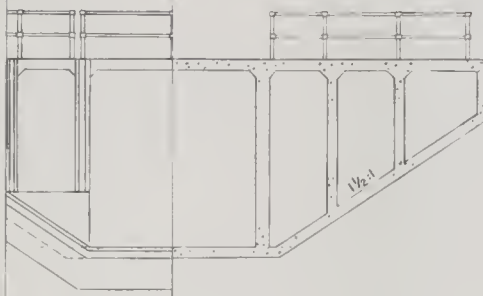




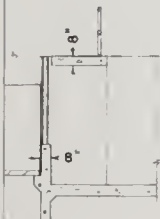
STATE OF CALIFORNIA DEPARTMENT OF WATER RESOURCES SOUTHERN CALIFORNIA DISTRICT	
PROJECT	FEATHER RIVER
FEATURE	SAN DIEGO AQUEOUCT DIVERSION AND METERING STRUCTURES
DESIGNED BY	CHAS. E. JOHNSON
CHECKED BY	W. H. JOHNSON
DATE	1947
BY	W. H. JOHNSON
DATE	1947
BY	W. H. JOHNSON
DATE	1947
BY	W. H. JOHNSON
DATE	1947

NO.	DATE	DESCRIPTION	BY	CHK.
1	1947	DESIGNED	W. H. JOHNSON	
2	1947	CHECKED	W. H. JOHNSON	
3	1947	BY	W. H. JOHNSON	
4	1947	DATE	1947	

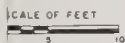




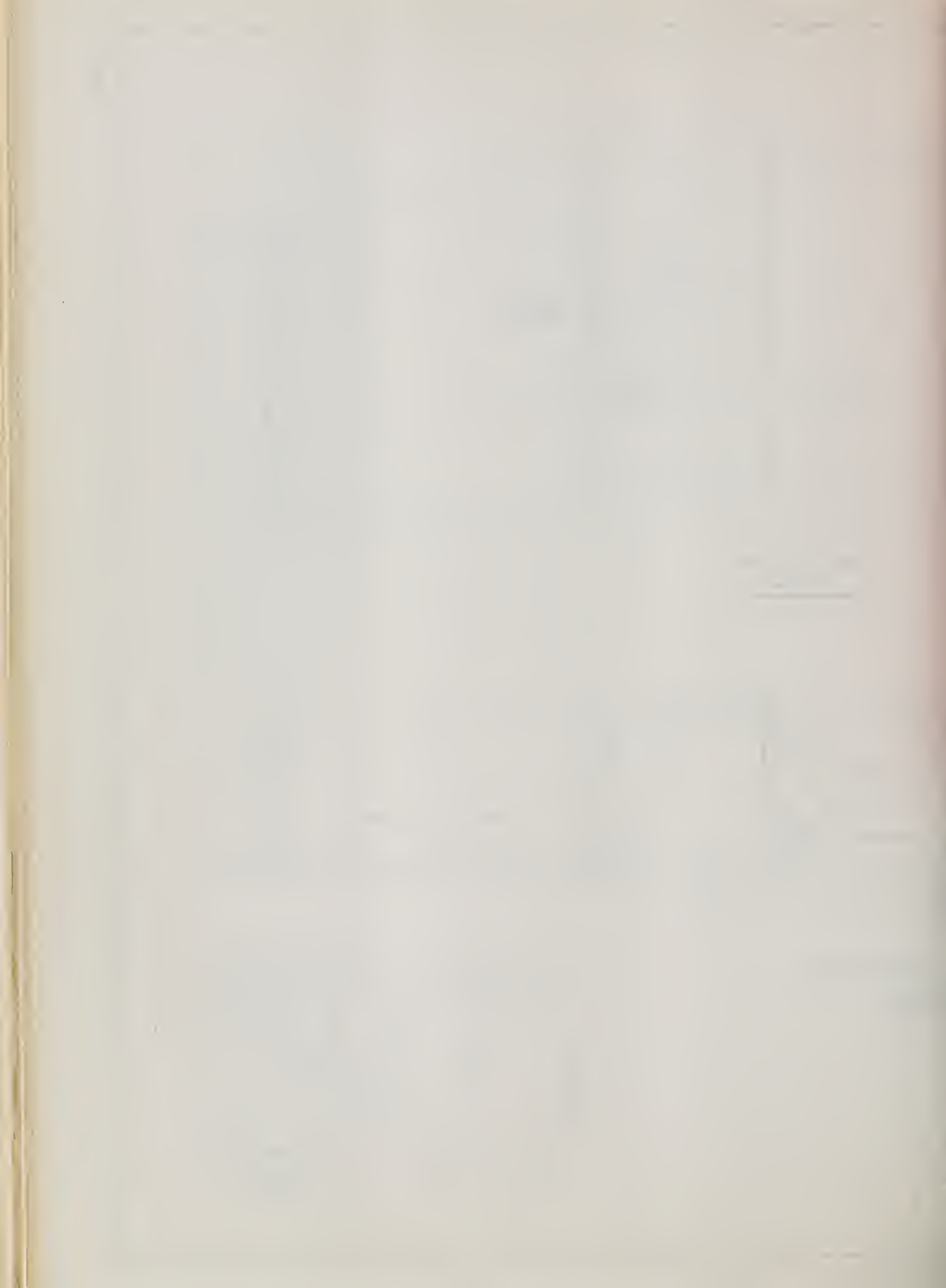
SECTION B-B

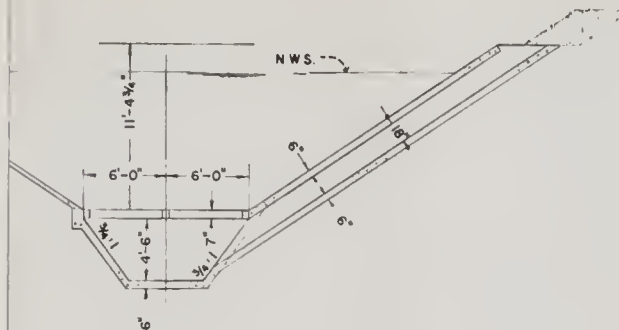


SECTION C-C



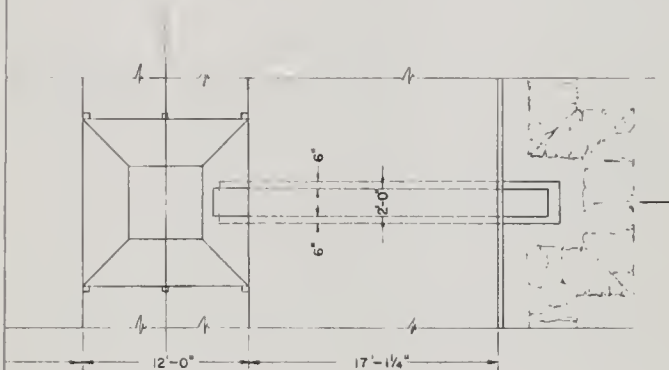
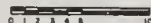
STATE OF CALIFORNIA DEPARTMENT OF WATER RESOURCES SOUTHERN CALIFORNIA DISTRICT			
PROJECT FEATHER RIVER		DATE 2/14/57	
FEATURE SAN DIEGO AQUEDUCT CANAL TERMINAL STRUCTURE		APPROVED <i>Max Berkman</i> DISTRICT ENGINEER	
DESIGNED <i>E. E. J.</i>	SUBMITTED <i>K. G. W.</i> DRAWING	APPROVED <i>Max Berkman</i> DISTRICT ENGINEER	
DRAWN C. M. V.	RECOMMENDED <i>James Thompson</i> DISTRICT ENGINEER	APPROVAL <i>R. M. Edmonston</i> DISTRICT ENGINEER	
CHECKED <i>F. J. L.</i>	APPROVAL <i>R. M. Edmonston</i> DISTRICT ENGINEER	DRAWING NO.	FILE NO.
DESCRIPTION	SUB	APPD	





SECTION A-A

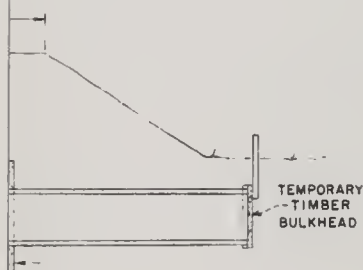
SCALE OF FEET



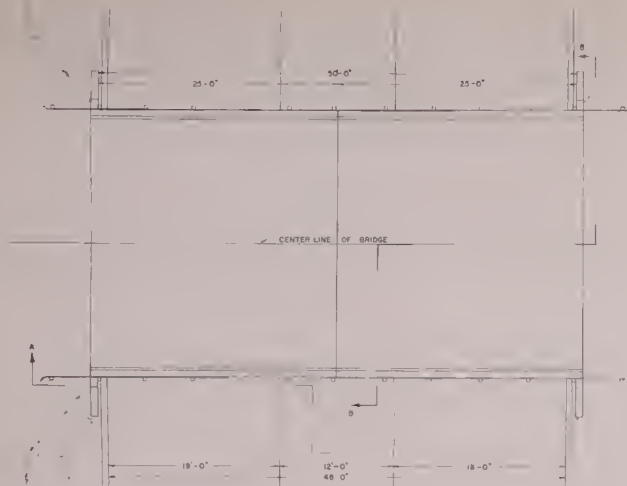
PLAN

SAND TRAP

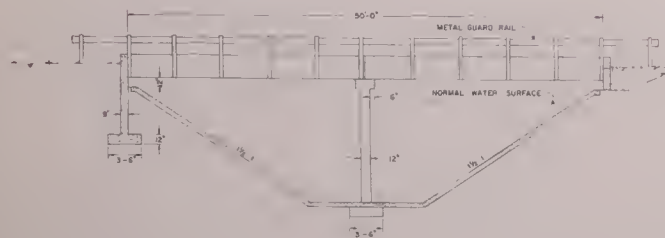
SCALE OF FEET



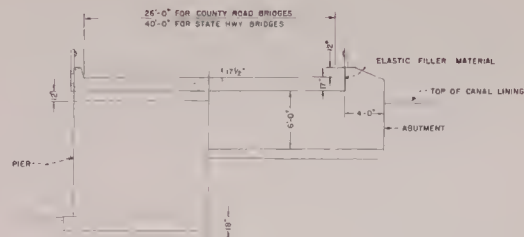
STATE OF CALIFORNIA DEPARTMENT OF WATER RESOURCES SOUTHERN CALIFORNIA DISTRICT			
PROJECT		FEATHER RIVER	
FEATURE		SAN DIEGO AQUEDUCT	
MISCELLANEOUS			
CANAL STRUCTURES			
DESIGNED:	CHECKED: <i>EEJ</i> DRAWING: <i>CMV</i> CHECKED: <i>SK</i>	APPROVED: <i>Max Borden</i> DISTRICT ENGINEER	DATE: <i>2/9/54</i>



PLAN

 SCALE OF FEET
 1" = 10'


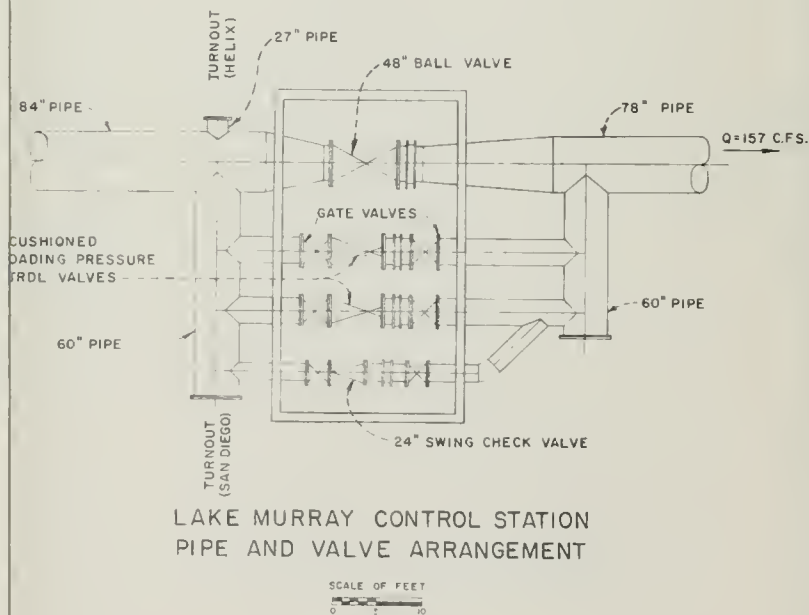
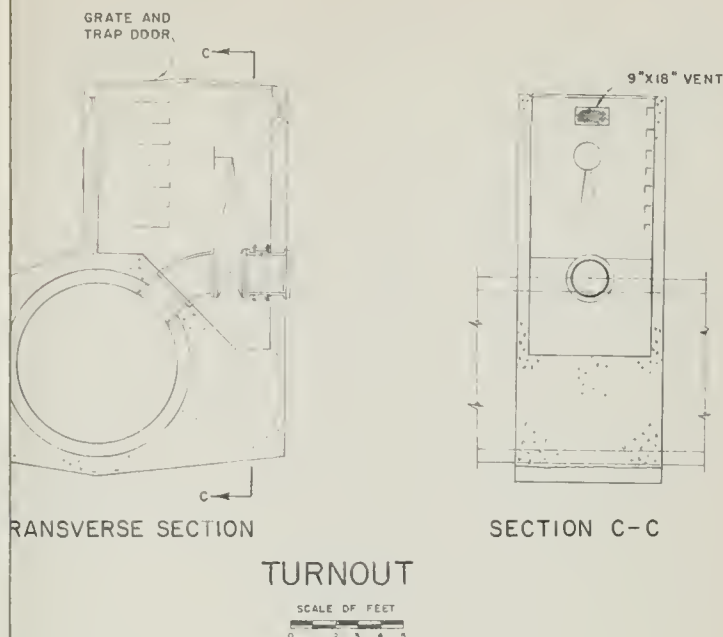
SECTION A-A

 SCALE OF FEET
 1" = 10'


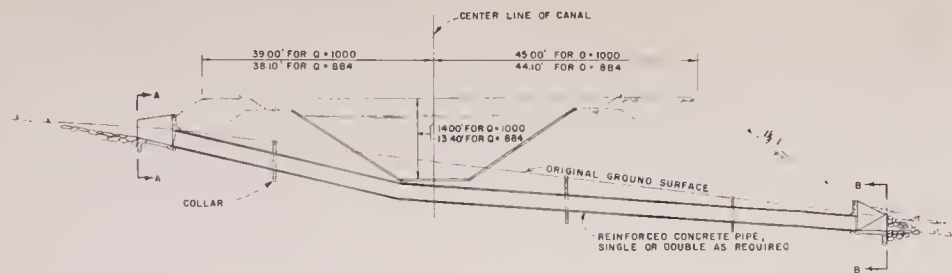
SECTION B-B

 SCALE OF FEET
 1" = 10'

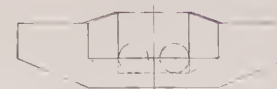
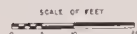
STATE OF CALIFORNIA DEPARTMENT OF WATER RESOURCES SOUTHERN CALIFORNIA DISTRICT			
PROJECT FEATHER RIVER			
FEATURE SAN DIEGO AQUEDUCT TYPICAL COUNTY AND STATE HIGHWAY BRIDGES			
DESIGNED 180	DRAWN 180	CHECKED 180	APPROVED 180
DATE 10/1/54			BY M. B. BROWN
PROJECT NO. 100-100-100			SCALE 1" = 10'



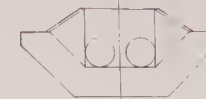
STATE OF CALIFORNIA DEPARTMENT OF WATER RESOURCES SOUTHERN CALIFORNIA DISTRICT			
PROJECT FEATHER RIVER		DATE 2/4/57	
FEATURE SAN DIEGO AQUEDUCT TYPICAL PIPE LINE STRUCTURES AND TRENCH DETAILS			
DESIGNED EEJ	SUBMITTED K. B. Williams 2/1/57	APPROVED Max Berkman	DISTRICT ENGINEER
DRAWN C.M.V.	RECOMMENDED R. P. P. [Signature]	APPROVAL RECOMMENDED R. P. P. [Signature]	DRAWING NO
CHECKED [Signature]	SUB	APPD	FILE NO



LONGITUDINAL SECTION THROUGH TYPICAL CULVERT



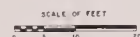
SECTION A-A



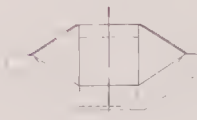
SECTION B-B



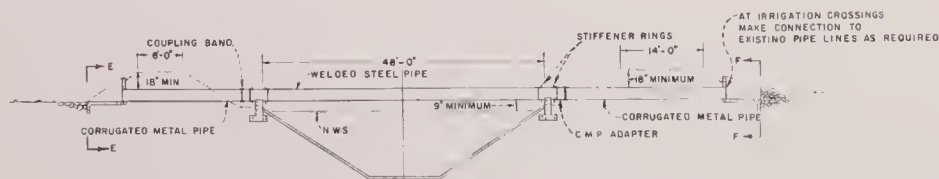
LONGITUDINAL SECTION THROUGH TYPICAL FLUME OVERCHUTE



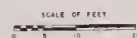
SECTION C-C



SECTION D-D



LONGITUDINAL SECTION THROUGH TYPICAL PIPE OVERCHUTE OR IRRIGATION CROSSING



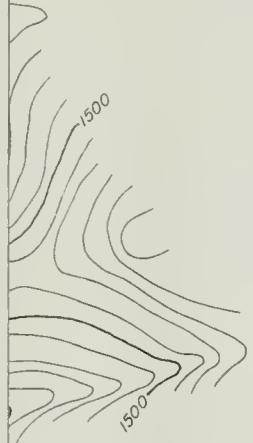
SECTION E-E



SECTION F-F

REV	DATE	DESCRIPTION	BY	APPD

STATE OF CALIFORNIA DEPARTMENT OF WATER RESOURCES SOUTHERN CALIFORNIA DISTRICT	
PROJECT FEATHER RIVER	DATE 2/4/57
FEATURE SAN DIEGO AQUEDUCT TYPICAL OVERCHUTES, CULVERTS AND IRRIGATION CROSSINGS	
DESIGNED E.E.J.	APPROVED M.S. DODMAN
DRAWN C.M.V.	CHECKED R.C.M.
DRAWING NO.	FILE NO.



ST EL. 1500.



500

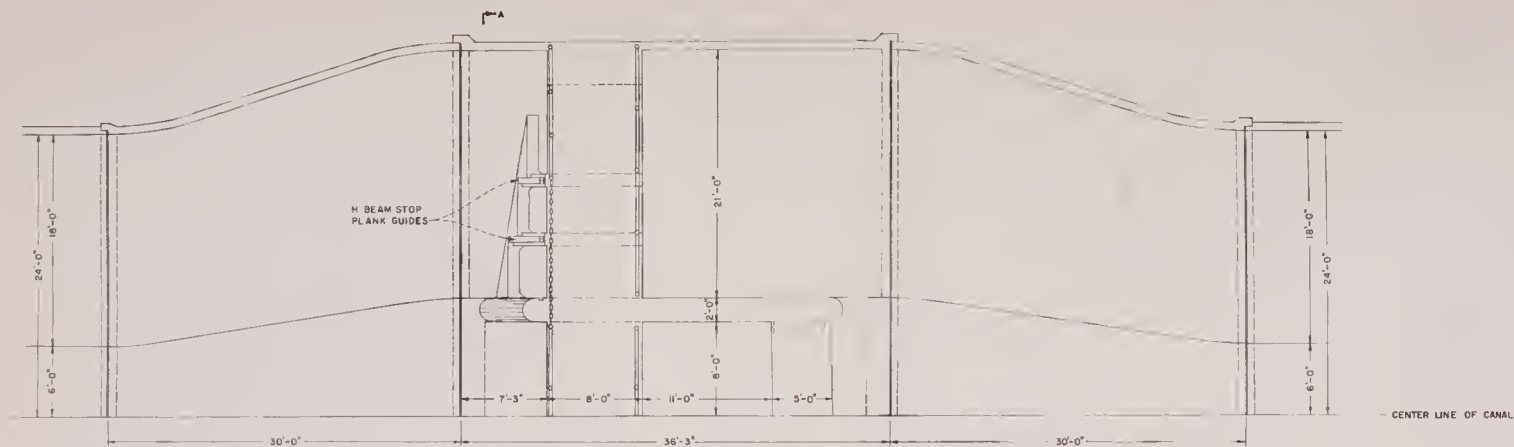


4600

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT
FEATHER RIVER PROJECT

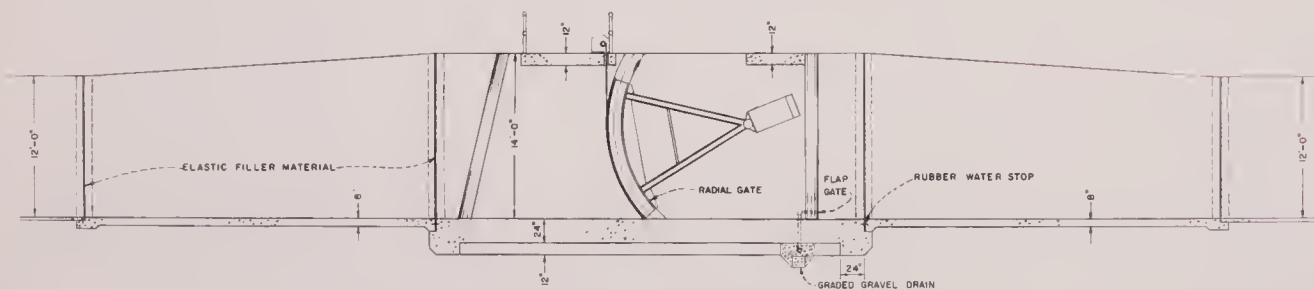
INVESTIGATION OF ALTERNATIVE AQUEDUCT
ROUTES TO SAN DIEGO COUNTY

AULD VALLEY DAM ON TUCALOTA CREEK
RESERVOIR STORAGE CAPACITY OF 38,000 ACRE—FEET
1957



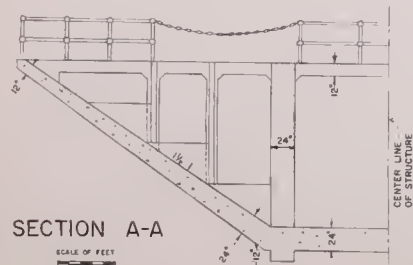
HALF PLAN

SCALE OF FEET
0 1 2 3 4 5 10



LONGITUDINAL SECTION

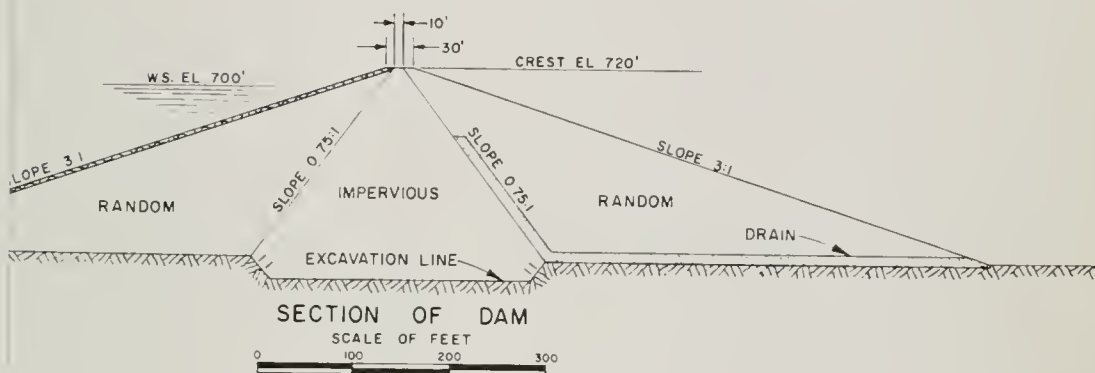
SCALE OF FEET
0 1 2 3 4 5 10



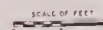
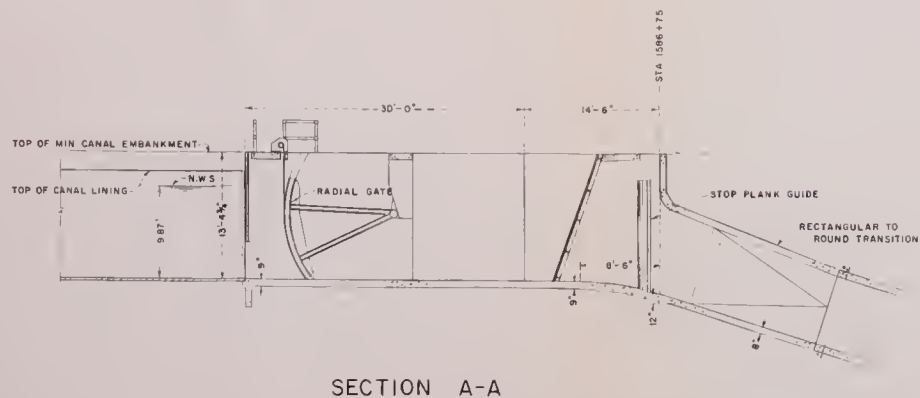
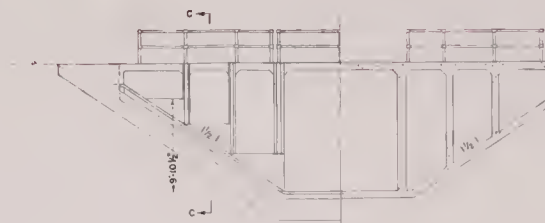
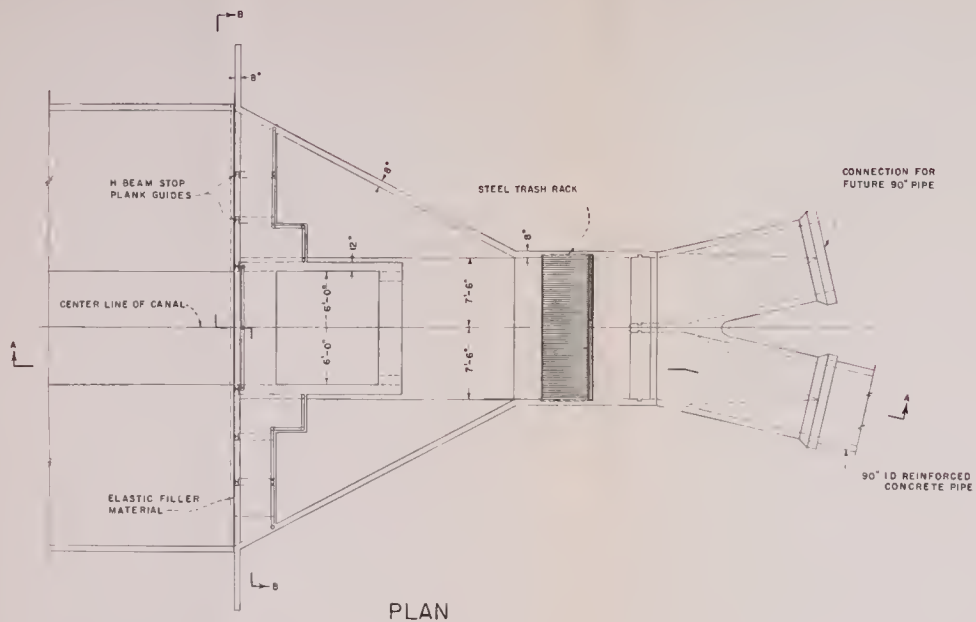
SECTION A-A

SCALE OF FEET
0 1 2 3 4 5 10

STATE OF CALIFORNIA DEPARTMENT OF WATER RESOURCES SOUTHERN CALIFORNIA DISTRICT			
PROJECT FEATHER RIVER			
FEATURE SAN DIEGO AQUEDUCT CHECK STRUCTURE			
DESIGNED E.E.J.	REVIEWED P.S. Wilson	APPROVED Max Burkman	DATE 2/28/57
CHECKED C.M.V.	APPROVED James J. Wilson	DESIGNED BY James J. Wilson	DATE 2/28/57
CHECKED R.P.P.	APPROVED R.P.P.	DESIGNED BY R.P.P.	DATE 2/28/57
REV	DATE	DESCRIPTION	BY

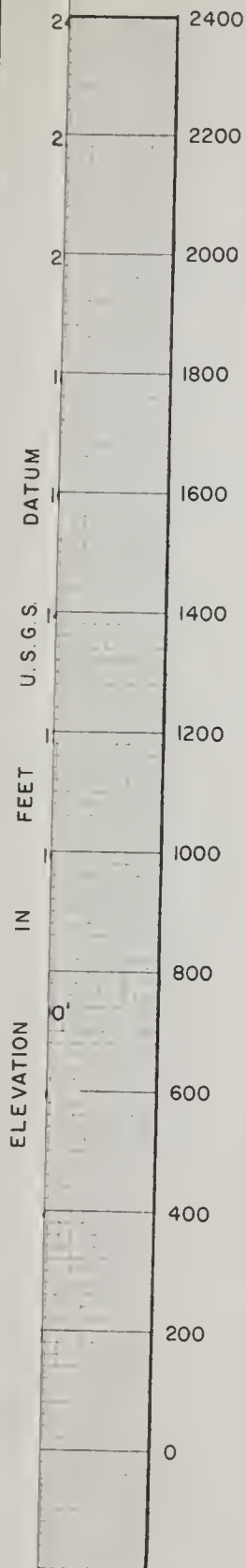


STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT
FEATHER RIVER PROJECT
INVESTIGATION OF ALTERNATIVE AQUEDUCT
ROUTES TO SAN DIEGO COUNTY
MINNEWAWA DAM ON JAMUL CREEK
RESERVOIR STORAGE CAPACITY OF 59,000 ACRE- FEET
1957

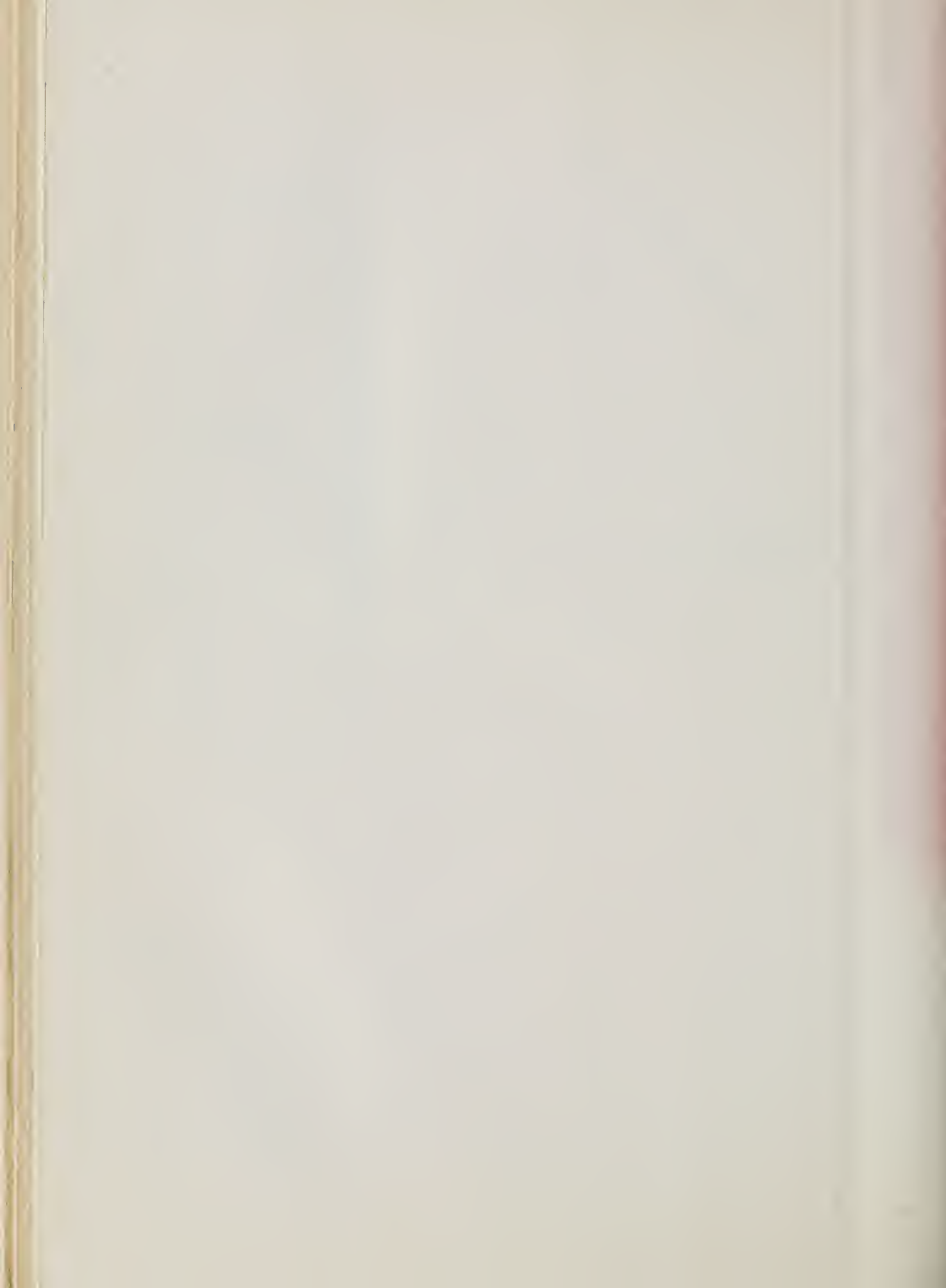


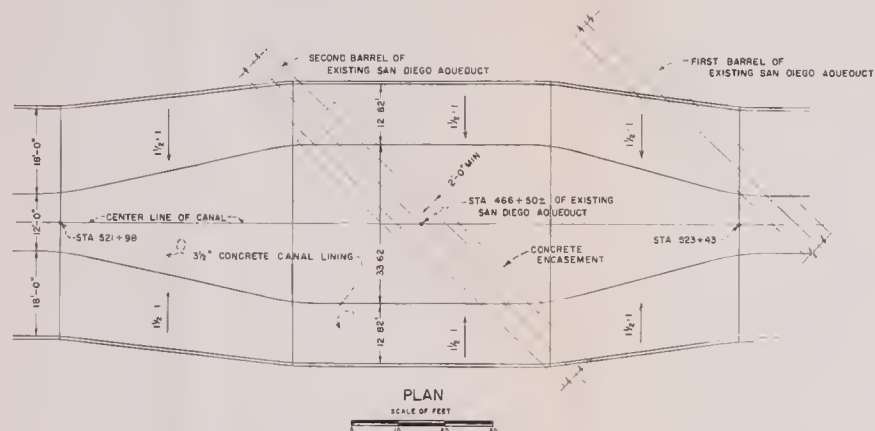
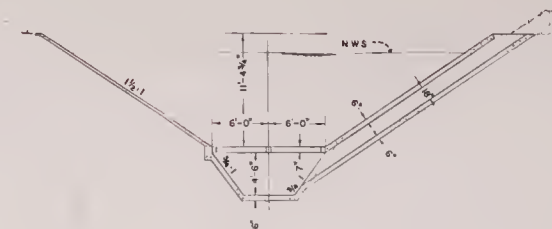
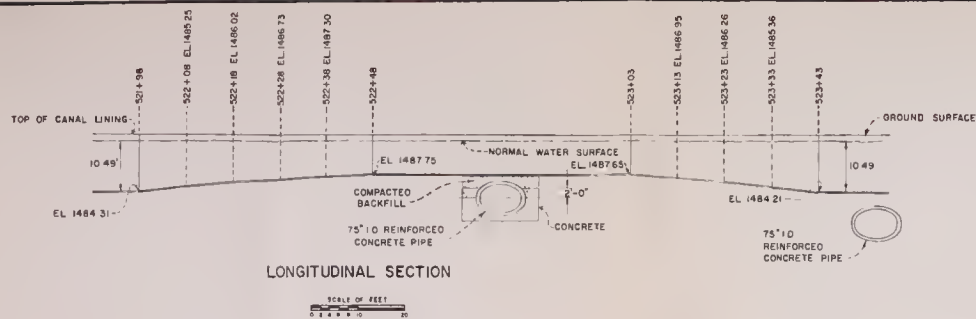
REV	DATE	DESCRIPTION	BY	APP'D

STATE OF CALIFORNIA DEPARTMENT OF WATER RESOURCES SOUTHERN CALIFORNIA DISTRICT			
PROJECT FEATHER RIVER			
FEATURE SAN DIEGO AQUEDUCT CANAL TERMINAL STRUCTURE			
DESIGNED C.E.V.	CHECKED C.M.V.	APPROVED [Signature]	DATE 3/6/67
APPROVAL RECOMMENDED [Signature]		DRAWING NO. FILE NO.	

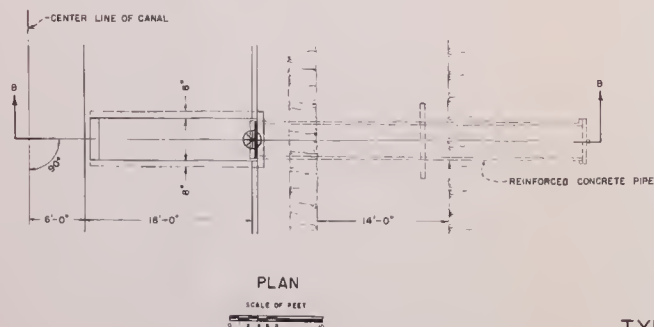


STATE OF CALIFORNIA
 DEPARTMENT OF WATER RESOURCES
 SOUTHERN CALIFORNIA DISTRICT
 FEATHER RIVER PROJECT
 INVESTIGATION OF ALTERNATIVE AQUEDUCT
 ROUTES TO SAN DIEGO COUNTY
 GENERAL PROFILE
 OF
 PROPOSED SAN DIEGO AQUEDUCT
 1957

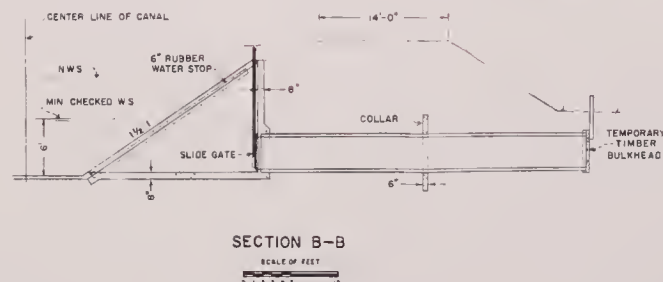




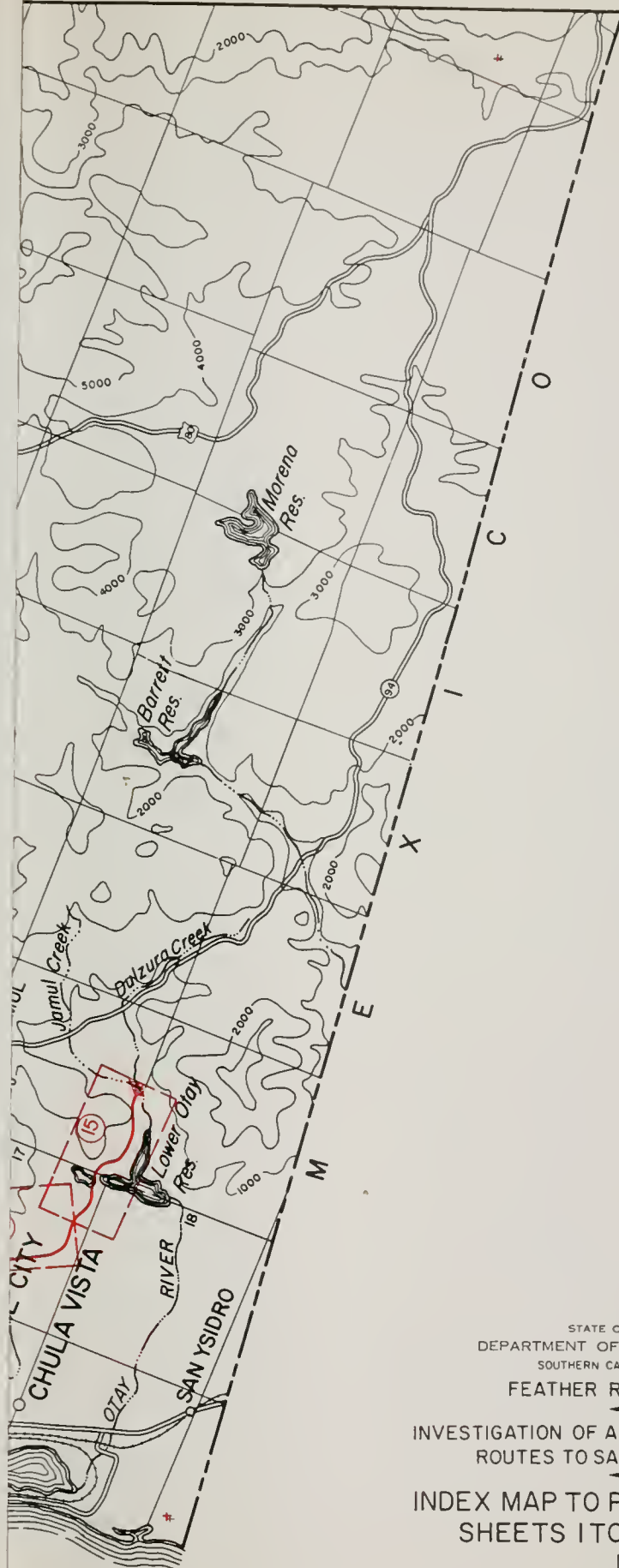
MODIFIED CANAL SECTION
STA.521+98 TO STA.523+43



TYPICAL TURNOUT



STATE OF CALIFORNIA DEPARTMENT OF WATER RESOURCES SOUTHERN CALIFORNIA DISTRICT			
PROJECT FEATHER RIVER			
FEATURE SAN DIEGO AQUEDUCT			
MISCELLANEOUS CANAL STRUCTURES			
NO. DRAWN E.B.J.	SUBMITTED 12/1/68 REVISIONS 1. <i>Revised</i> 2. <i>Revised</i> 3. <i>Revised</i>	APPROVED <i>Mr. Borden</i> District Engineer	DATE 12/1/68
NO. CHECKED J.H.	APPROVED R. M. <i>Edwards</i> District Engineer	DRAWING NO.	FILE NO.

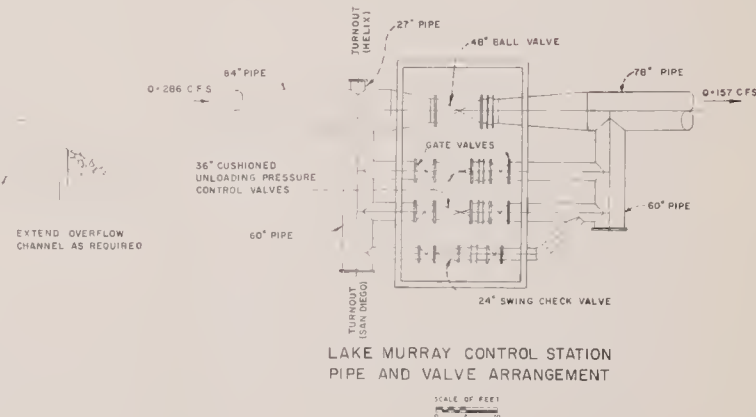
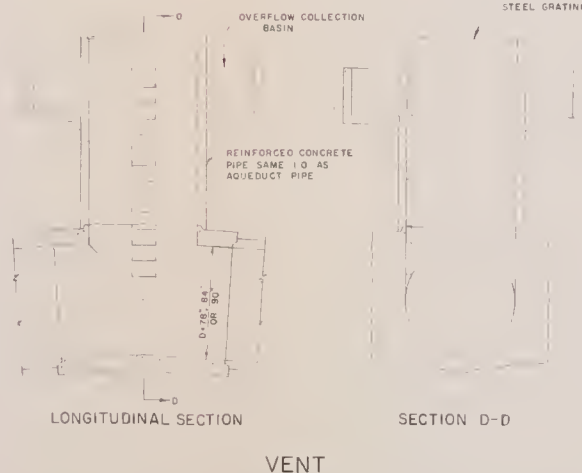
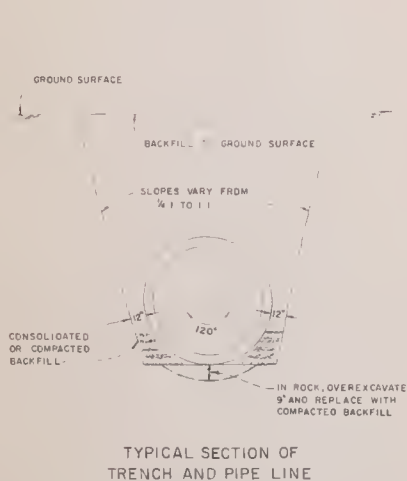
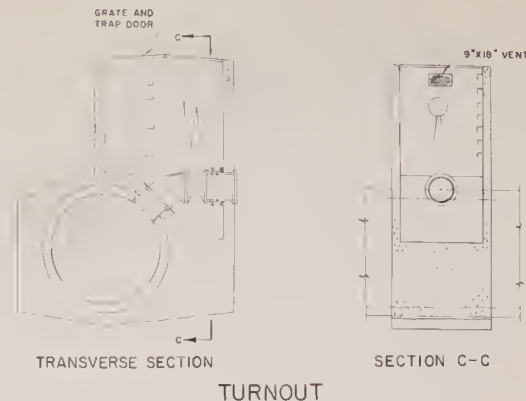
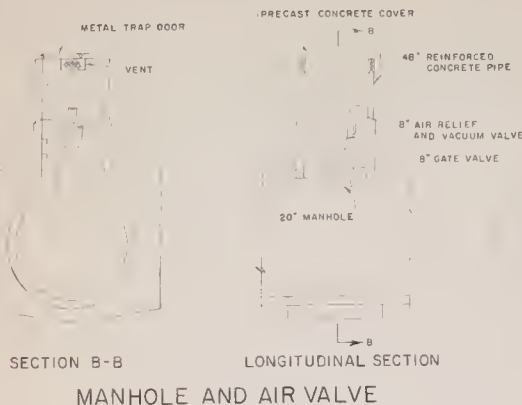
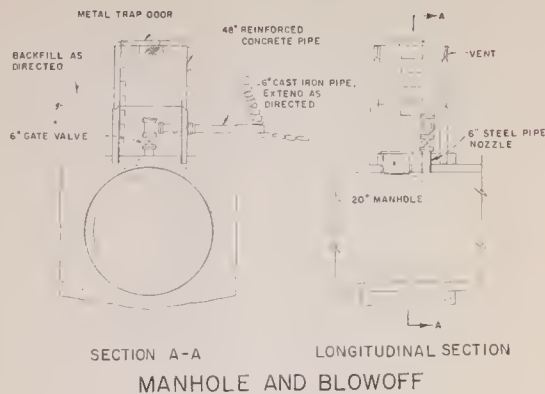


STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT
FEATHER RIVER PROJECT

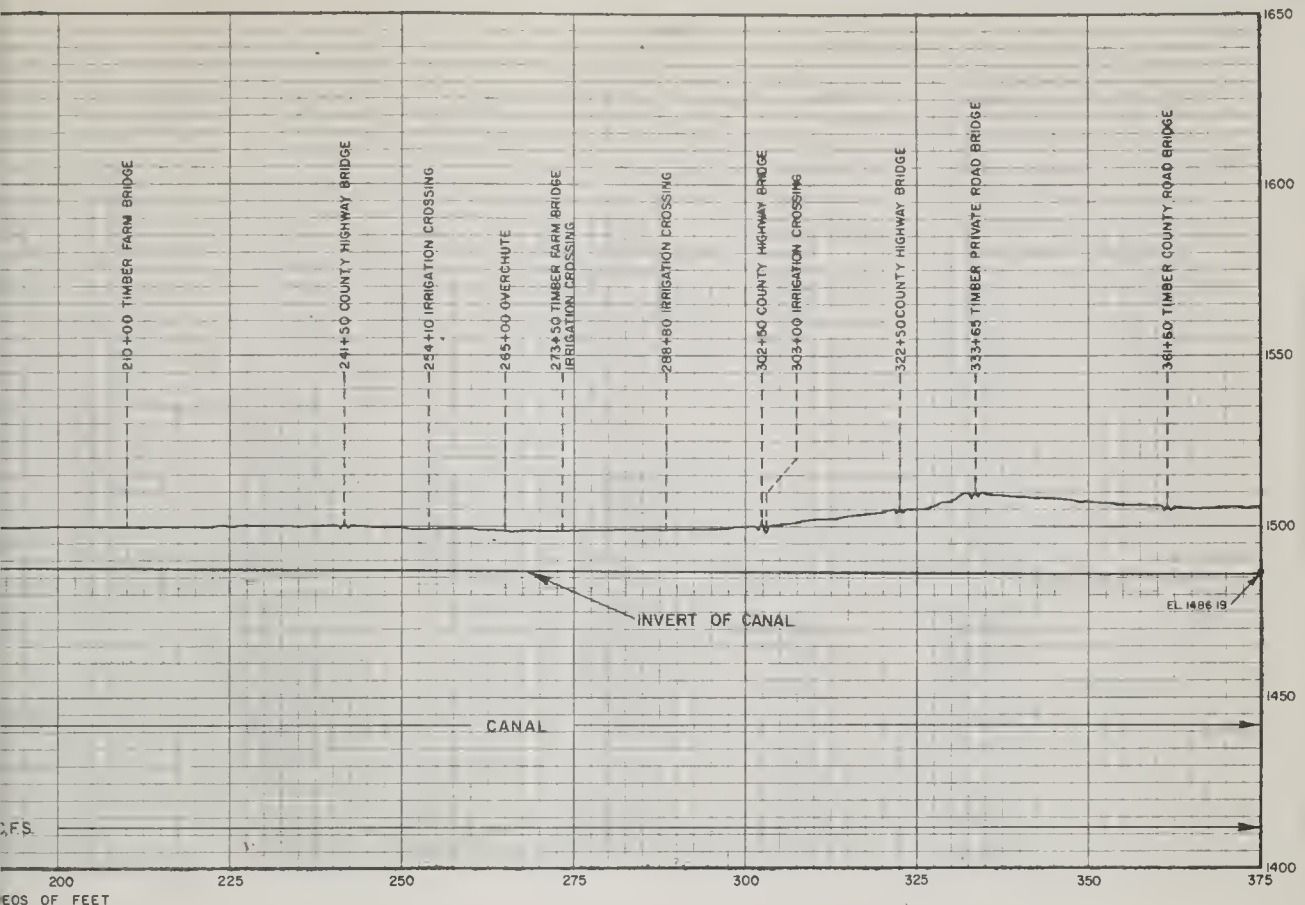
INVESTIGATION OF ALTERNATIVE AQUEDUCT
ROUTES TO SAN DIEGO COUNTY

INDEX MAP TO PLAN AND PROFILE
SHEETS 1 TO 15 INCLUSIVE
1957



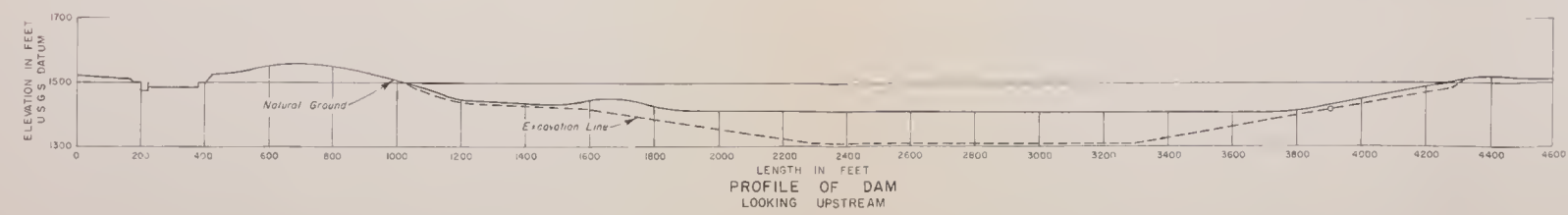
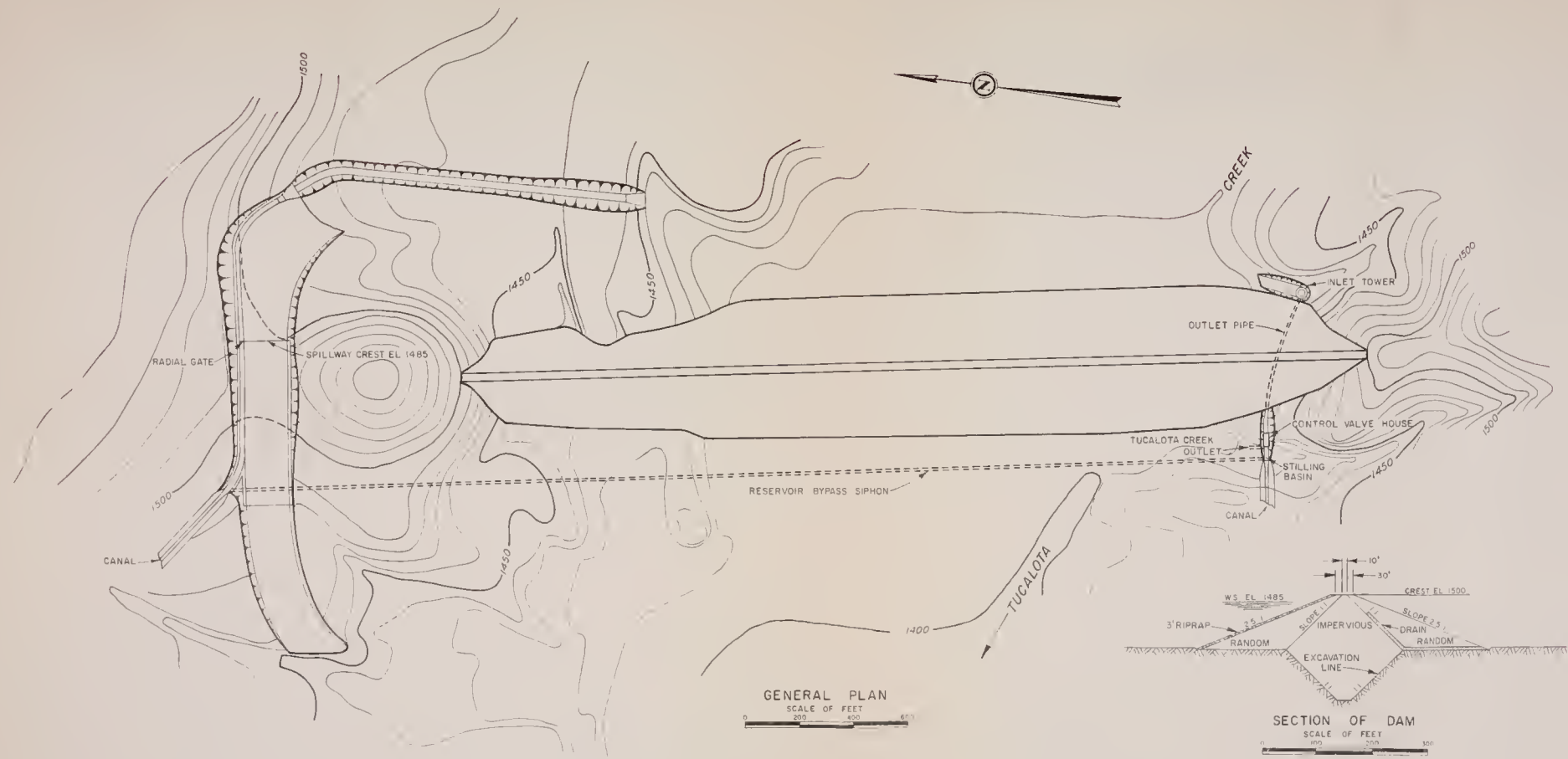


STATE OF CALIFORNIA DEPARTMENT OF WATER RESOURCES SOUTHERN CALIFORNIA DISTRICT			
PROJECT FEATHER RIVER			
FEATURE SAN DIEGO AQUEDUCT TYPICAL PIPE LINE STRUCTURES AND TRENCH DETAILS			
DESIGNED C. M. V.	REVIEWED C. M. V.	APPROVED Max B. B.	DATE 2-15-67
CHECKED C. M. V.	APPROVAL RECOMMENDATION C. M. V.	DRAWING NO. 10-111	FILE NO. 10-111

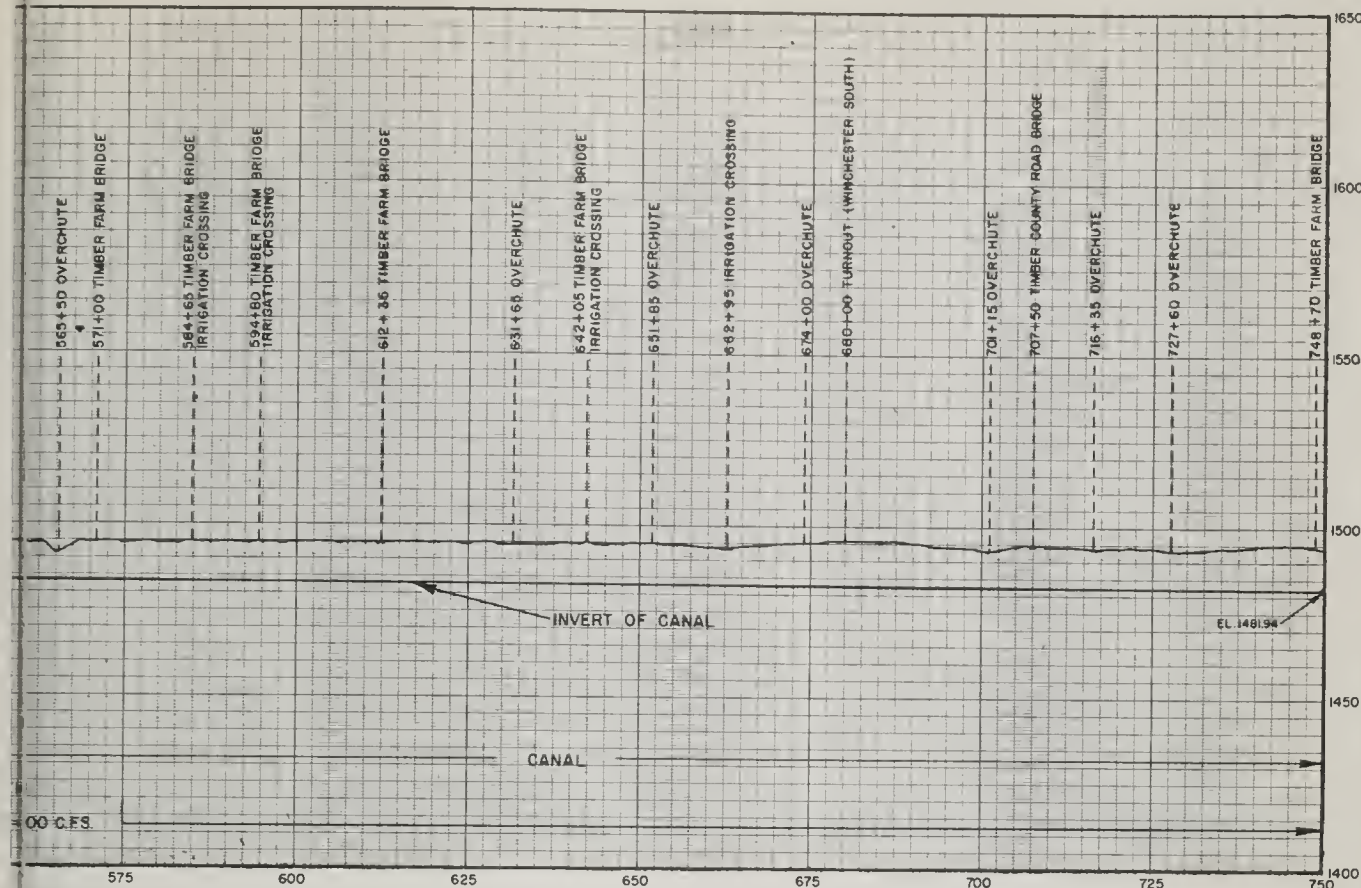


STATE OF CALIFORNIA DEPARTMENT OF WATER RESOURCES SOUTHERN CALIFORNIA DISTRICT			
PROJECT FEATHER RIVER			
FEATURE SAN DIEGO AQUEDUCT PLAN AND PROFILE STA. 0+00 TO STA. 375+00			
DESIGNED EEJ	SUBMITTED E.E. Wilson	APPROVED DATE 1/26/57	
DRAWN EEA	RECOMMENDED James H. Wilson	May Berkman District Engineer	
CHECKED R. M. Edmonston	APPROVAL RECOMMENDED R. M. Edmonston	DRAWING NO.	FILE NO.

REV	DATE	DESCRIPTION	SUB	APP'D

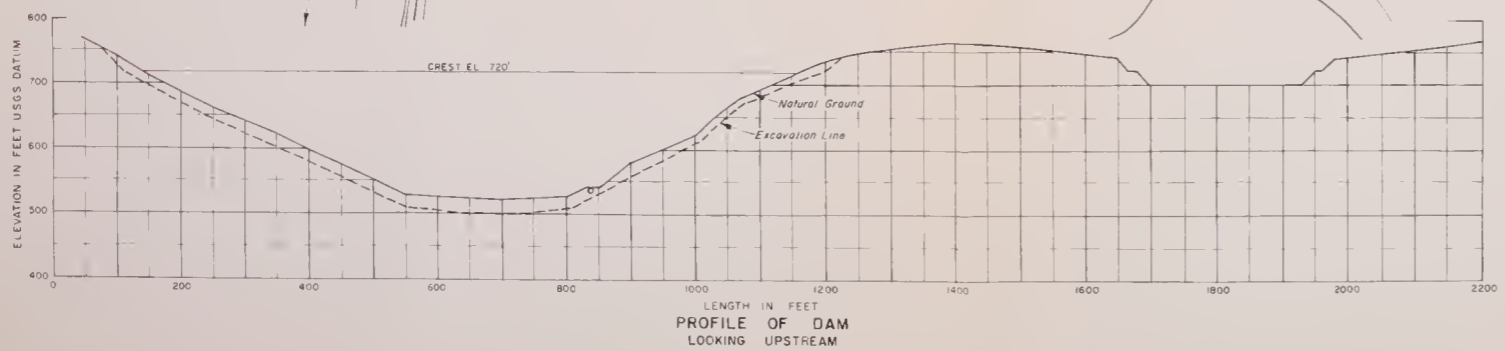
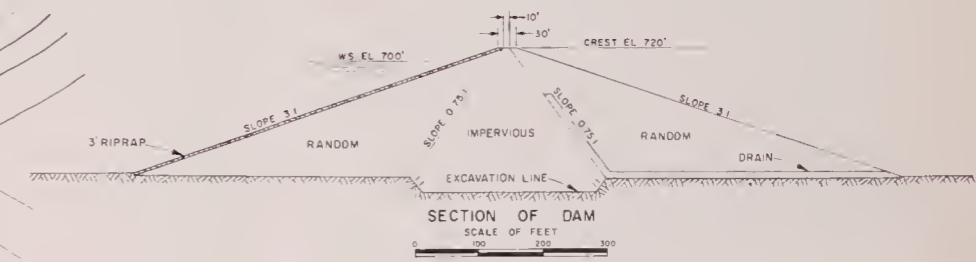
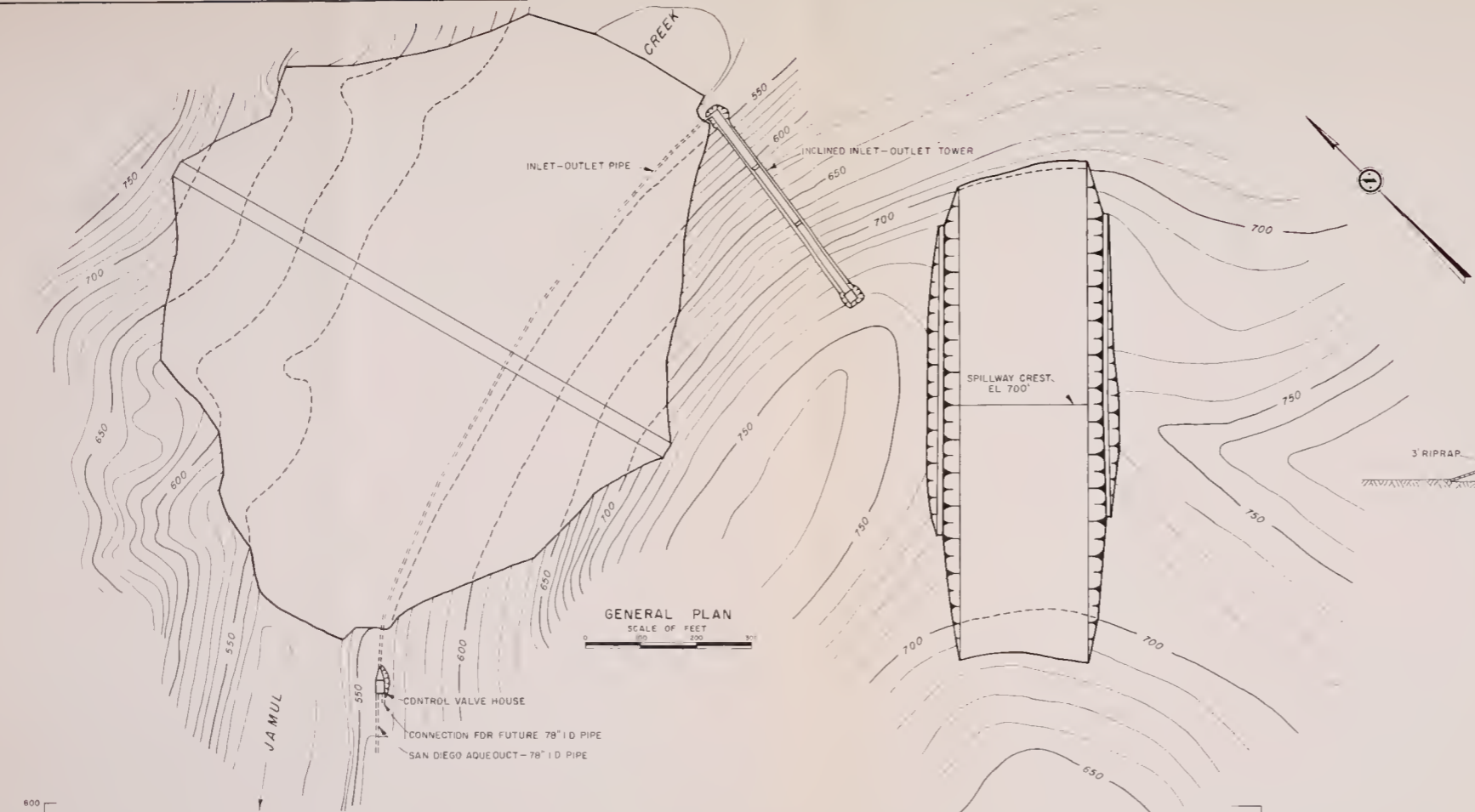


STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT
FEATHER RIVER PROJECT
INVESTIGATION OF ALTERNATIVE AQUEDUCT
ROUTES TO SAN DIEGO COUNTY
AULD VALLEY DAM ON TUCALOTA CREEK
RESERVOIR STORAGE CAPACITY OF 38,000 ACRE-Feet
1957

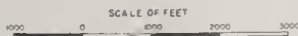
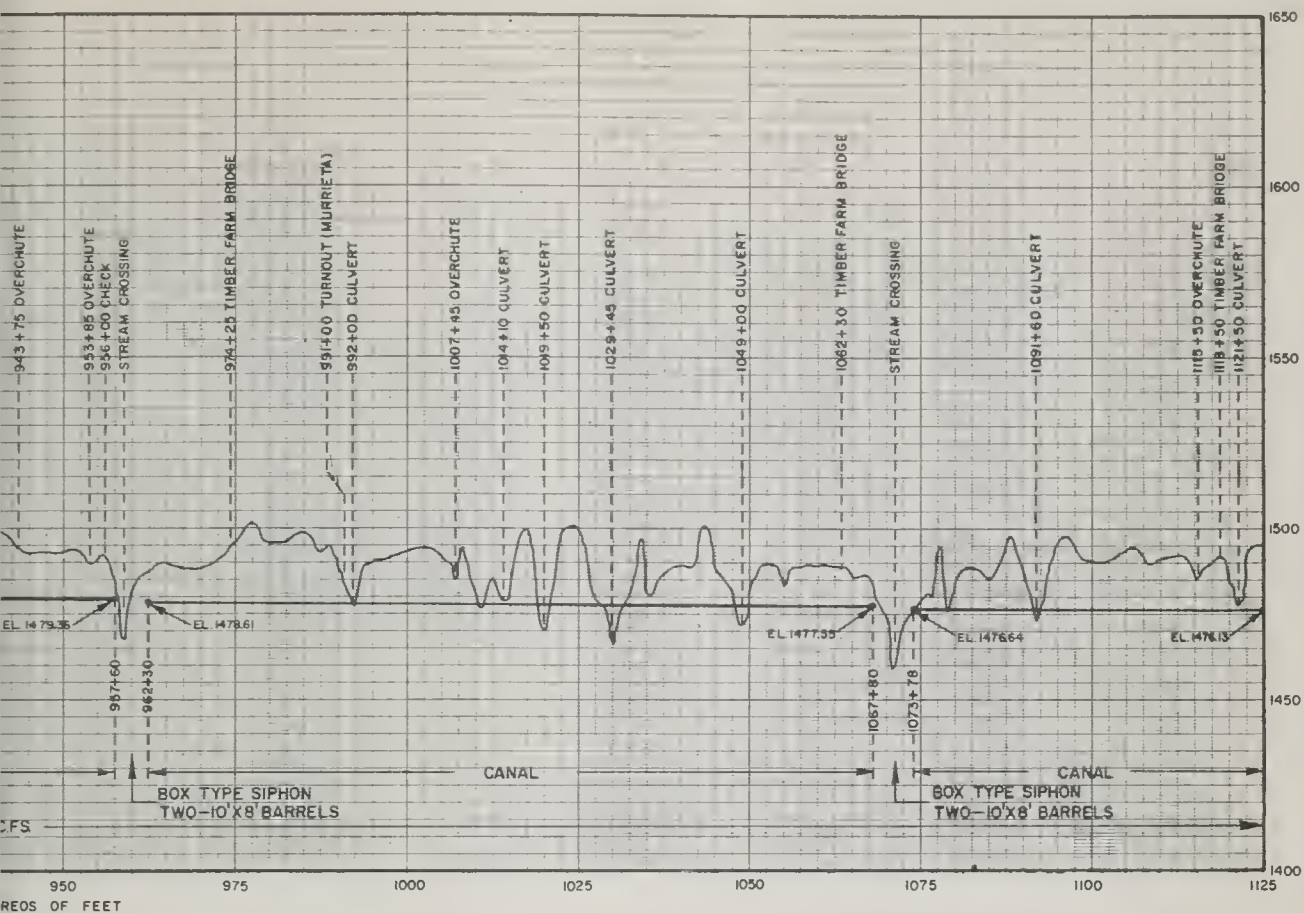


BASIC PROPERTIES			
r	n	s	
584	014	0001	

STATE OF CALIFORNIA DEPARTMENT OF WATER RESOURCES SOUTHERN CALIFORNIA DISTRICT			
PROJECT FEATHER RIVER			
FEATURE SAN DIEGO AQUEDUCT PLAN AND PROFILE STA. 375+00 TO STA 750+00			
DESIGNED E.E.J.	SUBMITTED K. A. White	APPROVED DATE 1/26/57	
DRAWN EEA	RECOMMENDED J. H. Myers	Max Bertram District Engineer	
CHECKED R. M. Edmonson	APPROVAL BY COMMENCED R. M. Edmonson	DRAWING NO	FILE NO
REV	DATE	DESCRIPTION	SUB APP'D

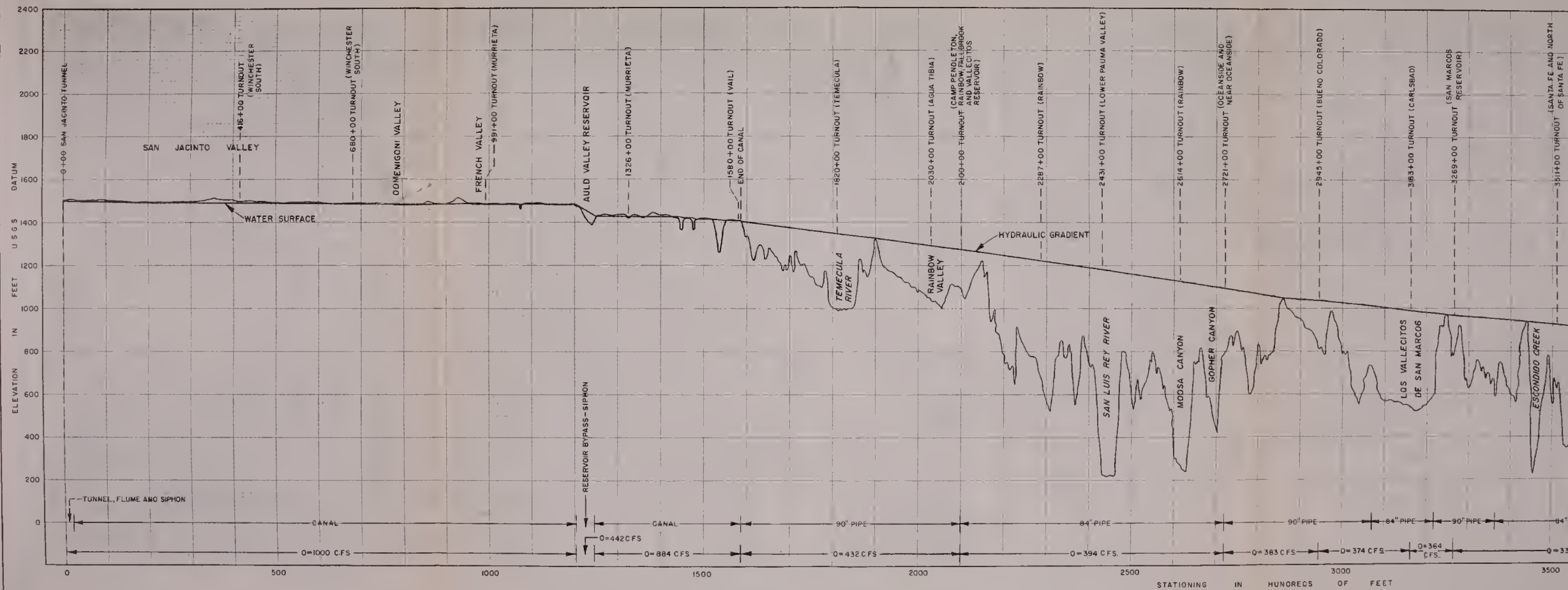


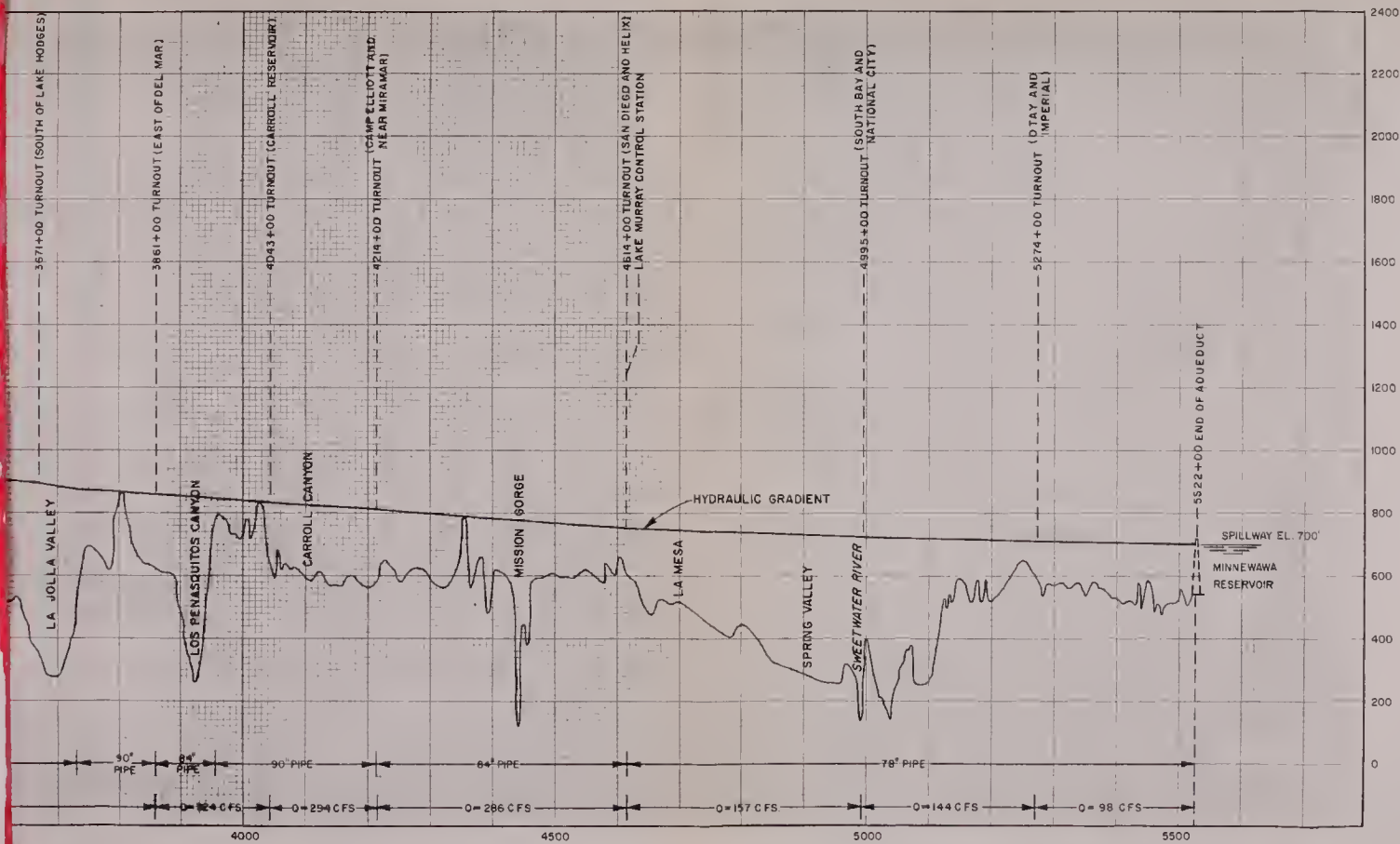
STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT
FEATHER RIVER PROJECT
INVESTIGATION OF ALTERNATIVE AQUEDUCT
ROUTES TO SAN DIEGO COUNTY
MINNEWAWA DAM ON JAMUL CREEK
RESERVOIR STORAGE CAPACITY OF 59,000 ACRE- FEET
1957



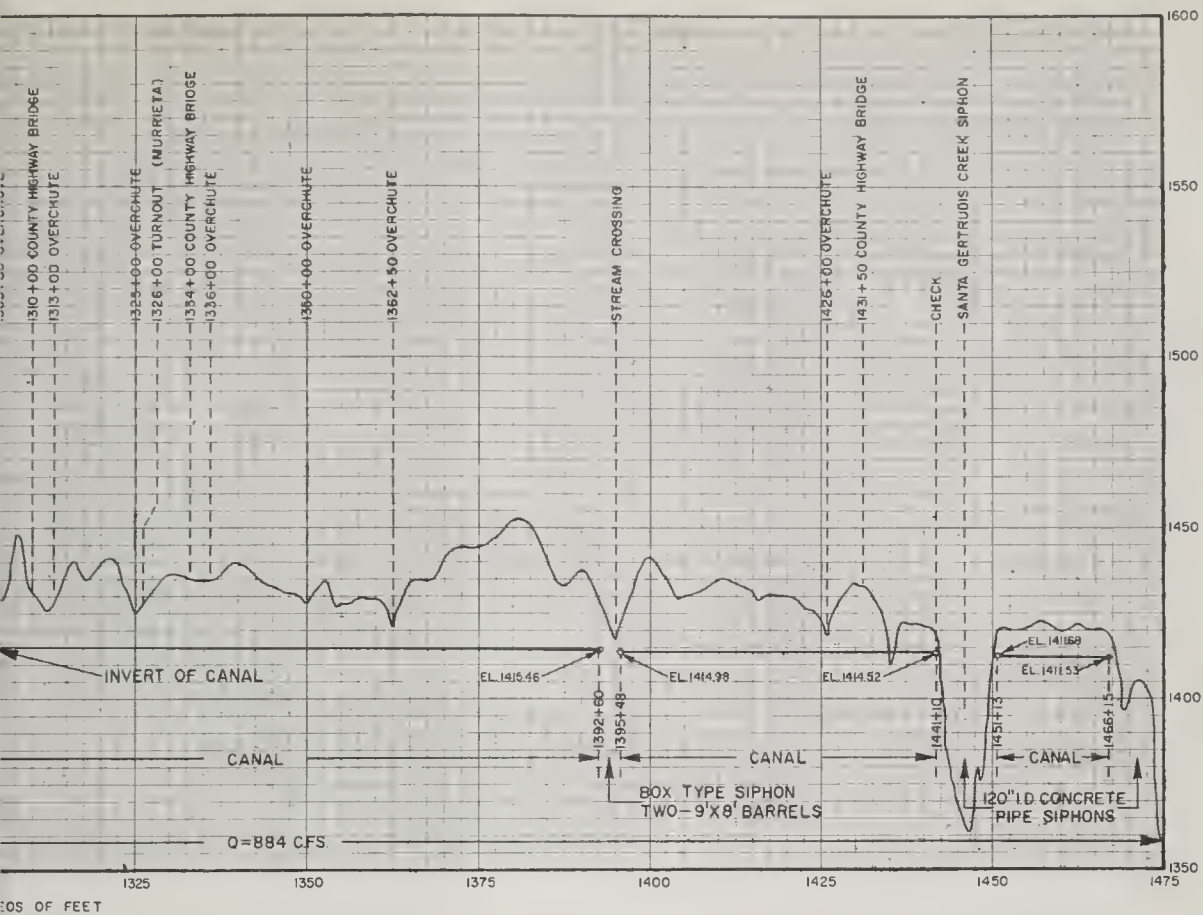
STATE OF CALIFORNIA DEPARTMENT OF WATER RESOURCES SOUTHERN CALIFORNIA DISTRICT			
PROJECT FEATHER RIVER		DATE 1/24/57	
FEATURE SAN DIEGO AQUEDUCT PLAN AND PROFILE STA. 750+00 TO STA. 1125+00		APPROVED: <i>Max R. Gordon</i> District Engineer	
DESIGNED <i>E.F.J.</i>	SUBMITTED <i>V.S. Williams</i>	APPROVAL RECOMMENDED <i>R. M. Edmonston</i>	
DRAWN <i>E.E.A.</i>	RECOMMENDED <i>James H. Hays</i>	DRAWING NO.	FILE NO.
CHECKED <i>J.H.</i>	APPROVAL RECOMMENDED <i>R. M. Edmonston</i>		

REV	DATE	DESCRIPTION	SUB	APPD

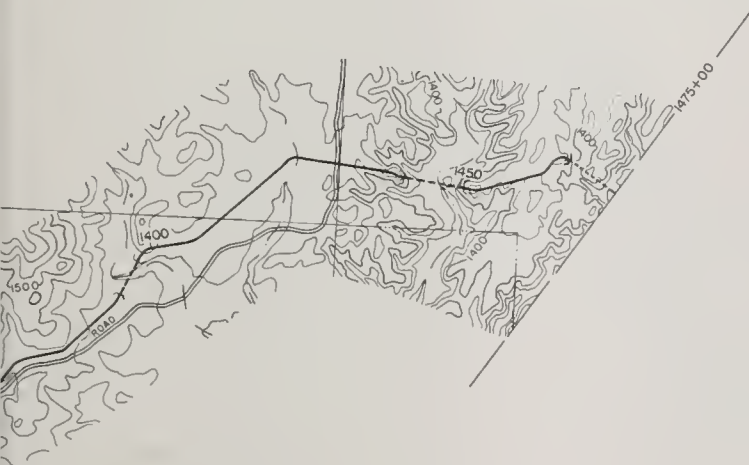




STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT
FEATHER RIVER PROJECT
INVESTIGATION OF ALTERNATIVE AQUEDUCT
ROUTES TO SAN DIEGO COUNTY
GENERAL PROFILE
OF
PROPOSED SAN DIEGO AQUEDUCT
1957



FEET

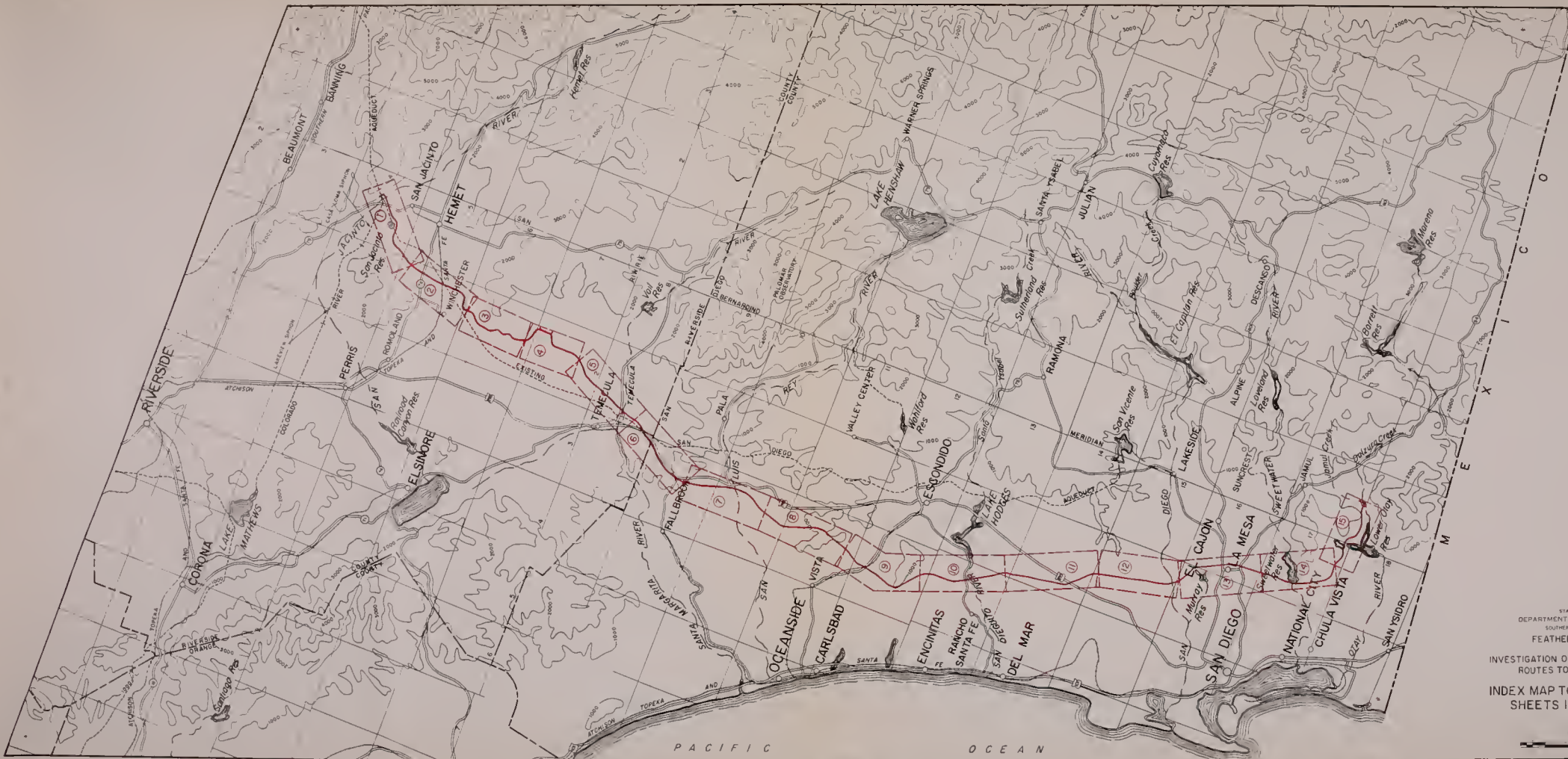


FEET

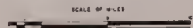
HYDRAULIC PROPERTIES				
Q	r	n	s	
4 1000	584	014	0001	
4 884	556	014	0001	

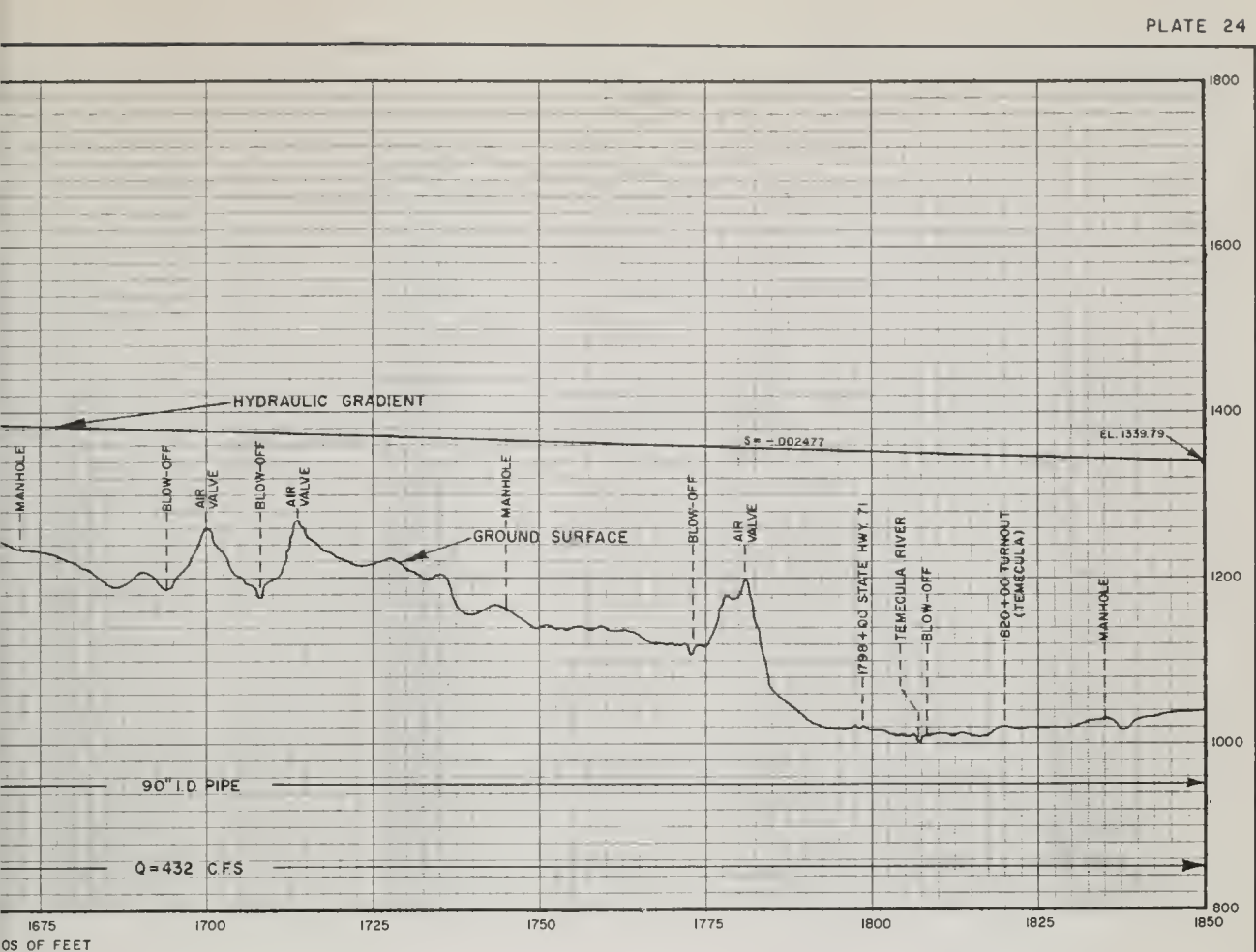
REV	DATE	DESCRIPTION	SUB	APP'D

STATE OF CALIFORNIA DEPARTMENT OF WATER RESOURCES SOUTHERN CALIFORNIA DISTRICT			
PROJECT FEATHER RIVER			
FEATURE SAN DIEGO AQUEDUCT PLAN AND PROFILE STA 1425+00 TO STA 1475+00			
DESIGNED EES	SUBMITTED K. B. [Signature] [Signature] & DATE	APPROVED DATE 1/26/57	
DRAWN JPB & EEA	RECOMMENDED [Signature] [Signature]	Max [Signature] District Engineer	
CHECKED [Signature]	APPROVAL RECOMMENDED R. M. [Signature] Principal Hydraulic Engineer	DRAWING NO	FILE NO



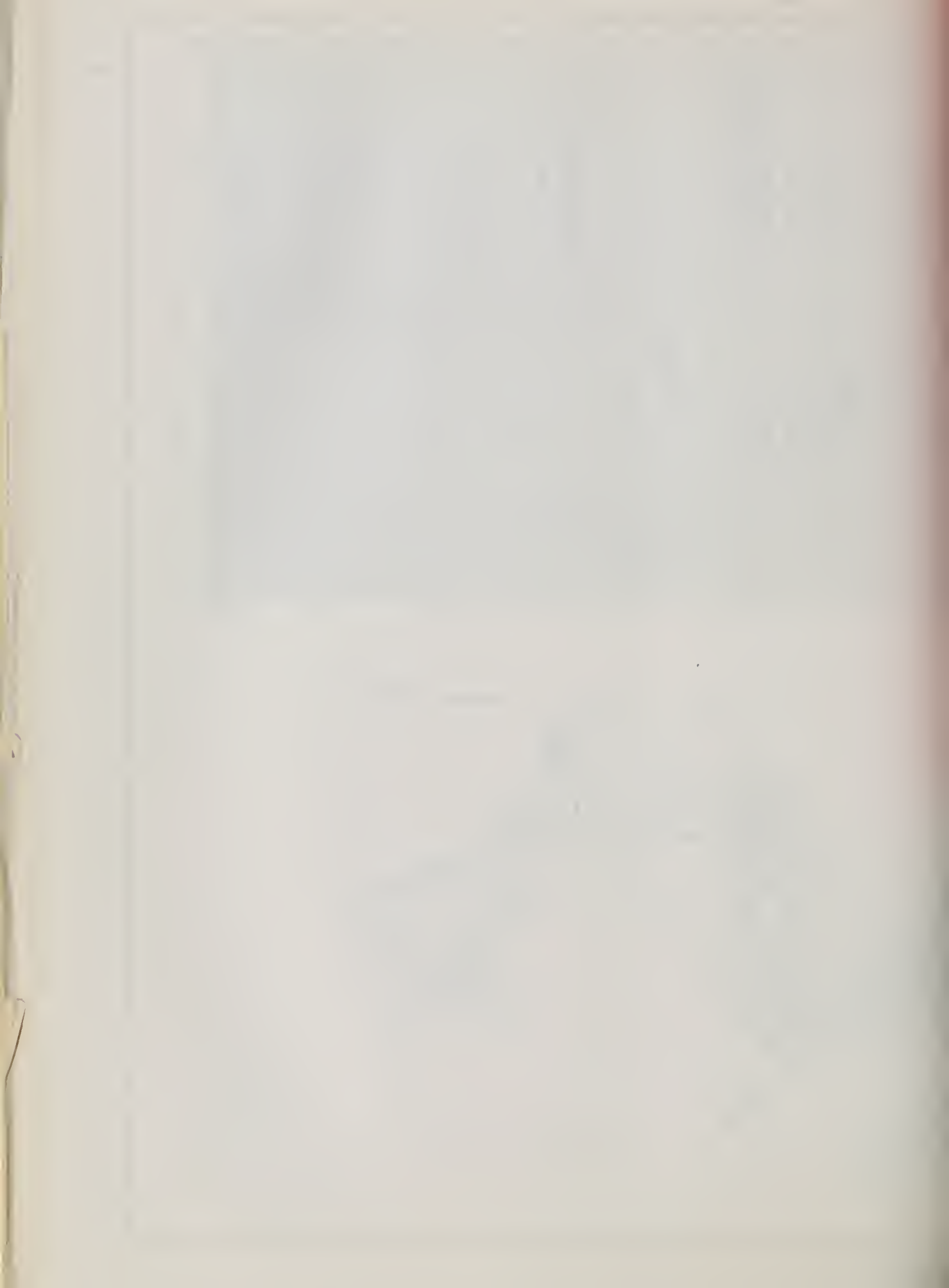
STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT
FEATHER RIVER PROJECT
INVESTIGATION OF ALTERNATIVE AQUEDUCT
ROUTES TO SAN DIEGO COUNTY
INDEX MAP TO PLAN AND PROFILE
SHEETS 1 TO 15 INCLUSIVE
1957

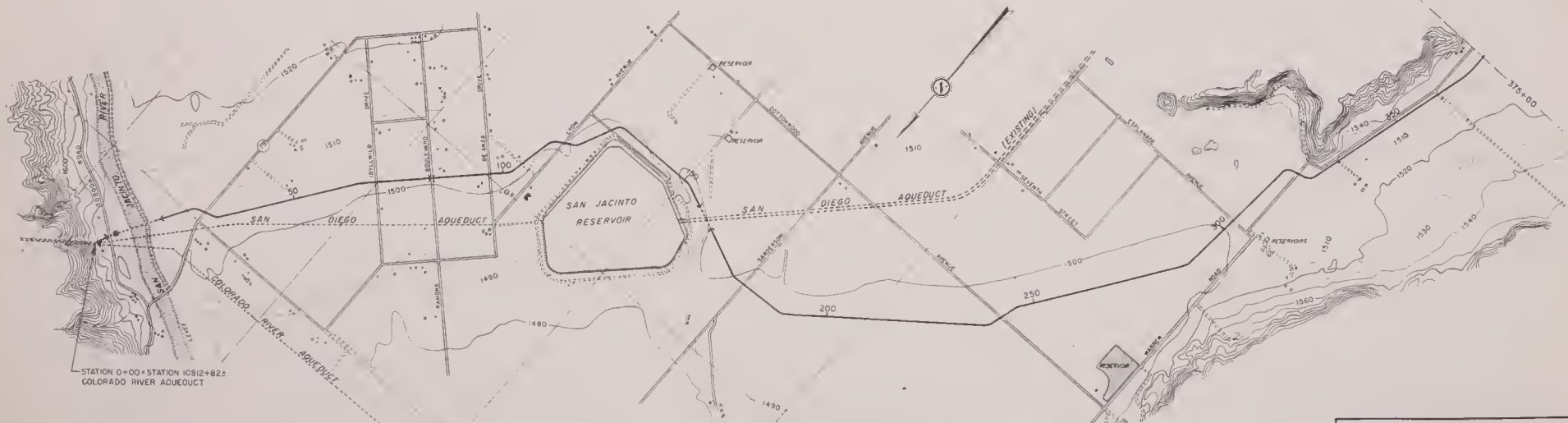
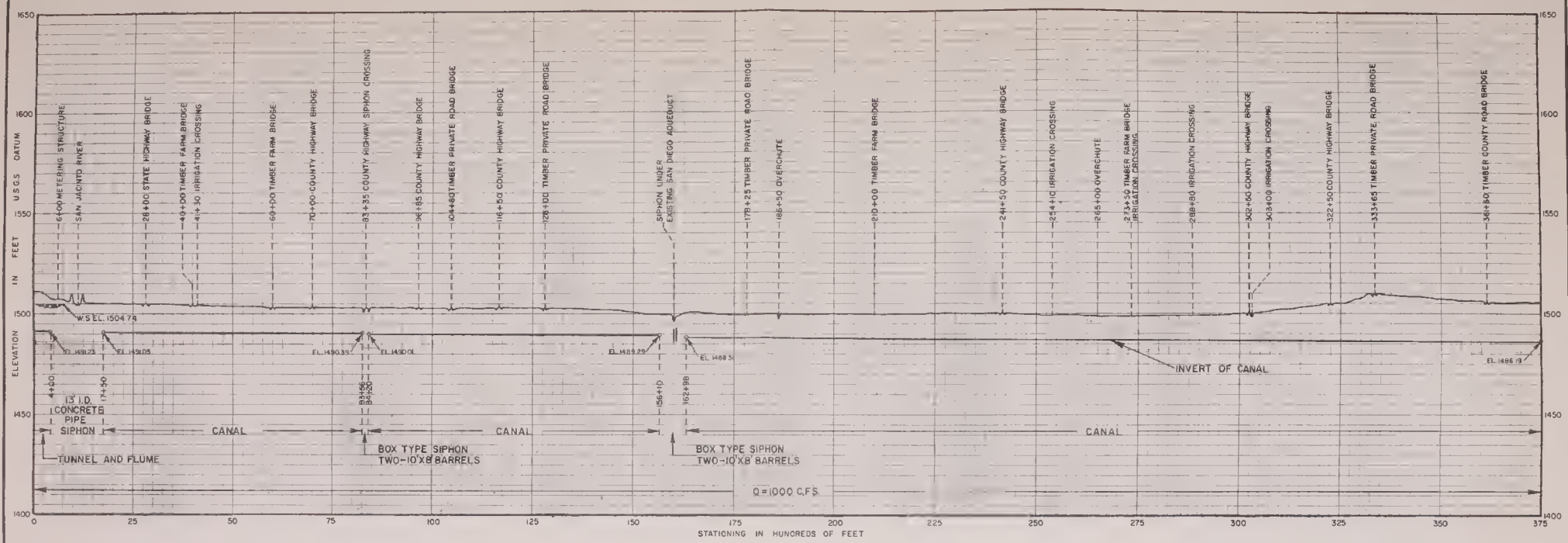




PIPE LINE HYDRAULIC PROPERTIES						
DIA.	Q	A	V	n	r	s
90"	432	4418	978	.0115	1825	.002477

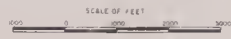
STATE OF CALIFORNIA DEPARTMENT OF WATER RESOURCES SOUTHERN CALIFORNIA DISTRICT			
PROJECT		FEATHER RIVER	
FEATURE		SAN DIEGO AQUEDUCT	
		PLAN AND PROFILE	
		STA 1475+00 TO STA 1850+00	
DESIGNED	SUBMITTED	APPROVED	DATE
EEJ	R.B. Wilkes Principal Engineer	<i>[Signature]</i> District Engineer	1/24/67
DRAWN	RECOMMENDED	<i>Max Beckman</i>	
EEA	<i>[Signature]</i> District Engineer	District Engineer	
CHECKED	APPROVAL	DRAWING NO	FILE NO
<i>[Signature]</i>	R.M. Williams Principal Hydraulic Engineer		



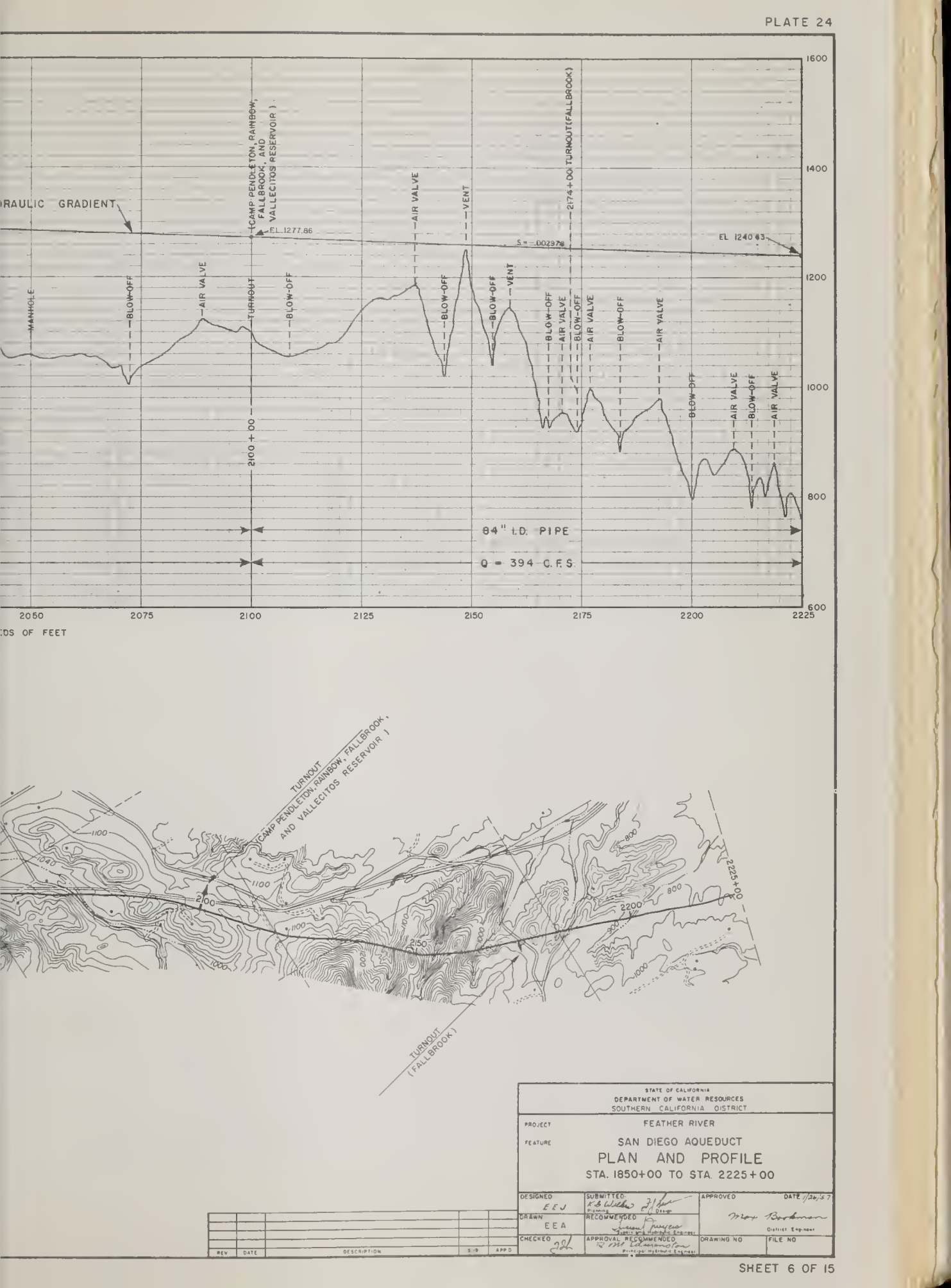
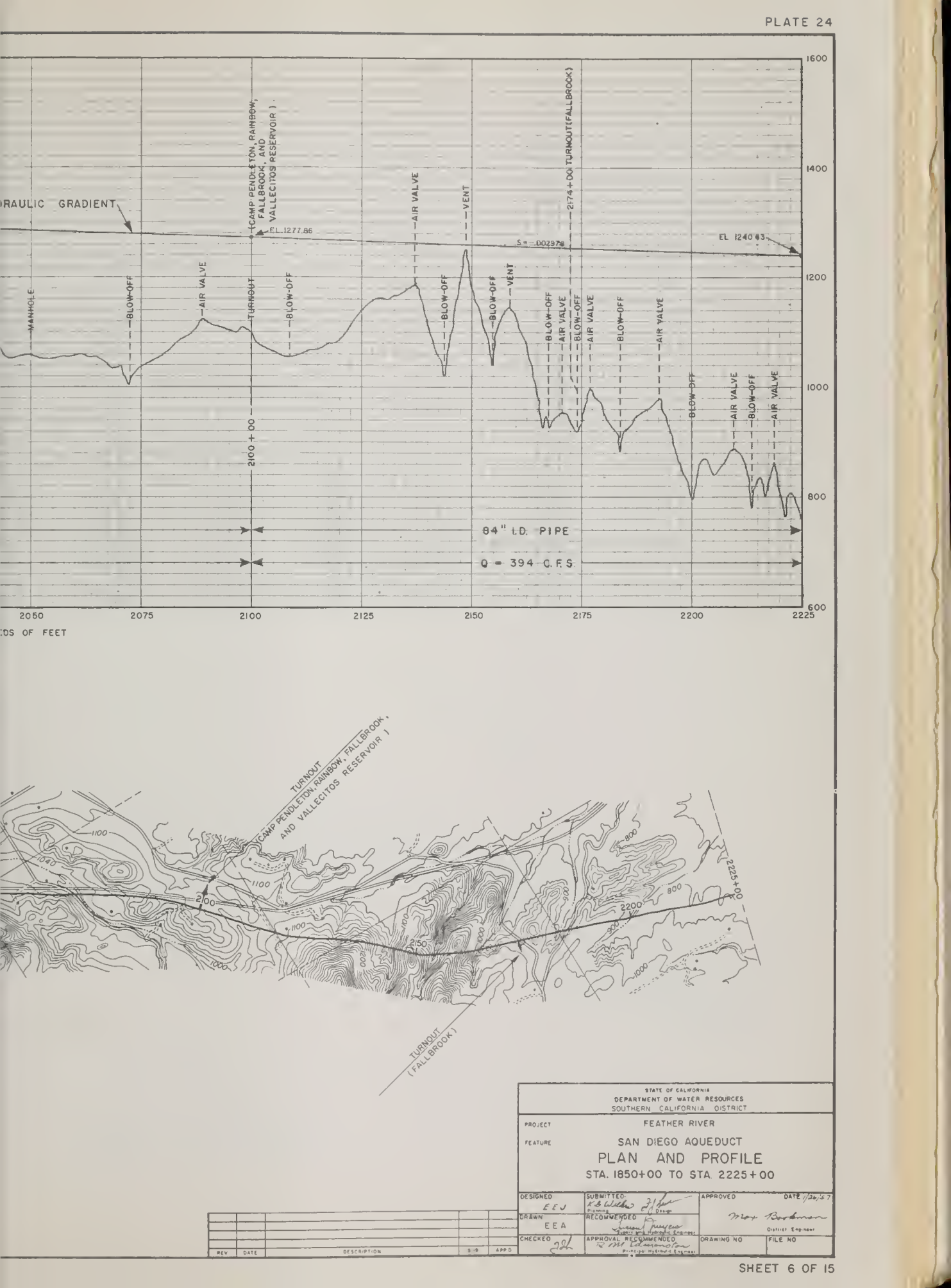


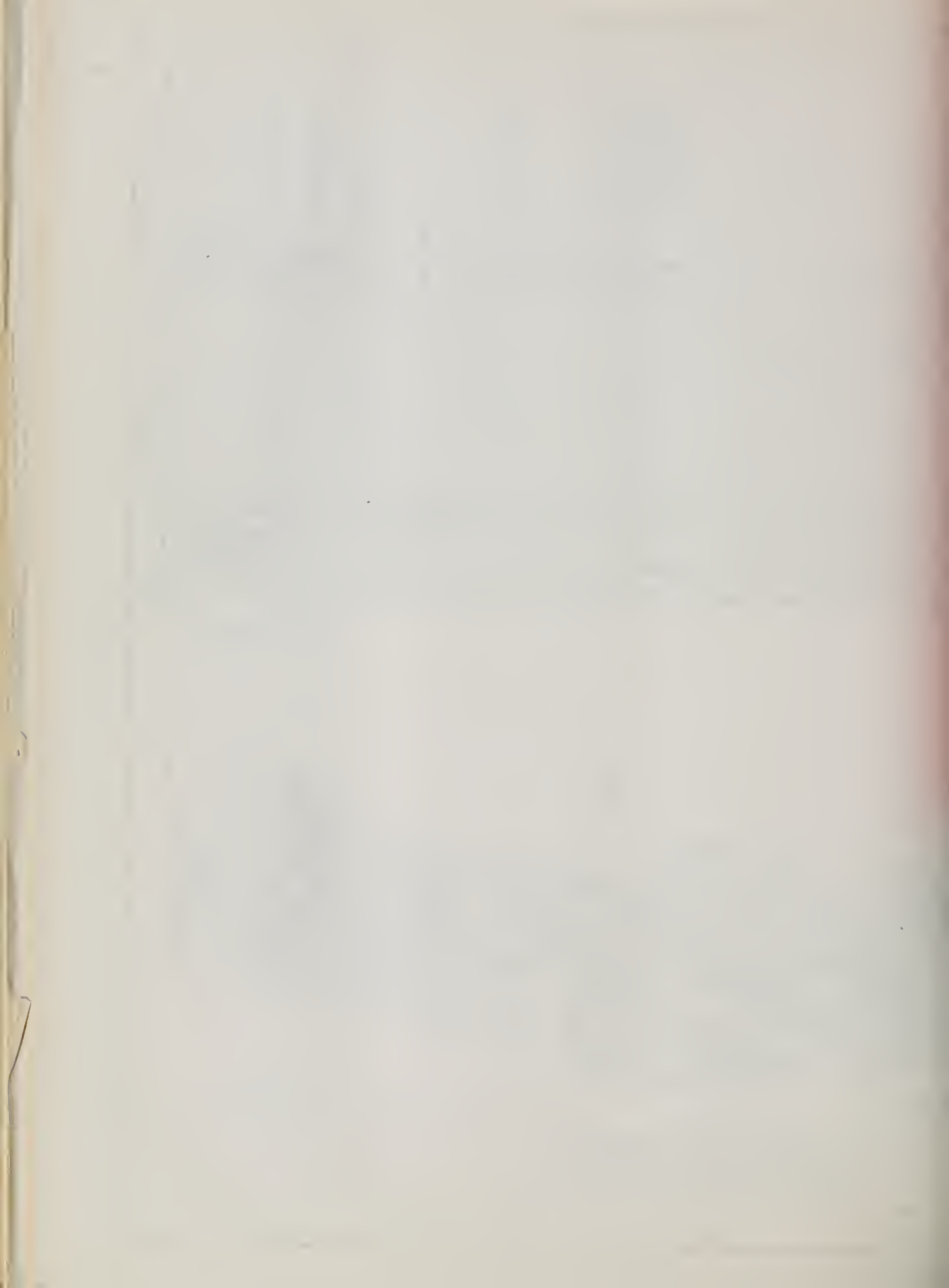
NOTE
TOPOGRAPHY ADAPTED FROM U.S.G.S. 7 1/2 MINUTE QUADRANGLES

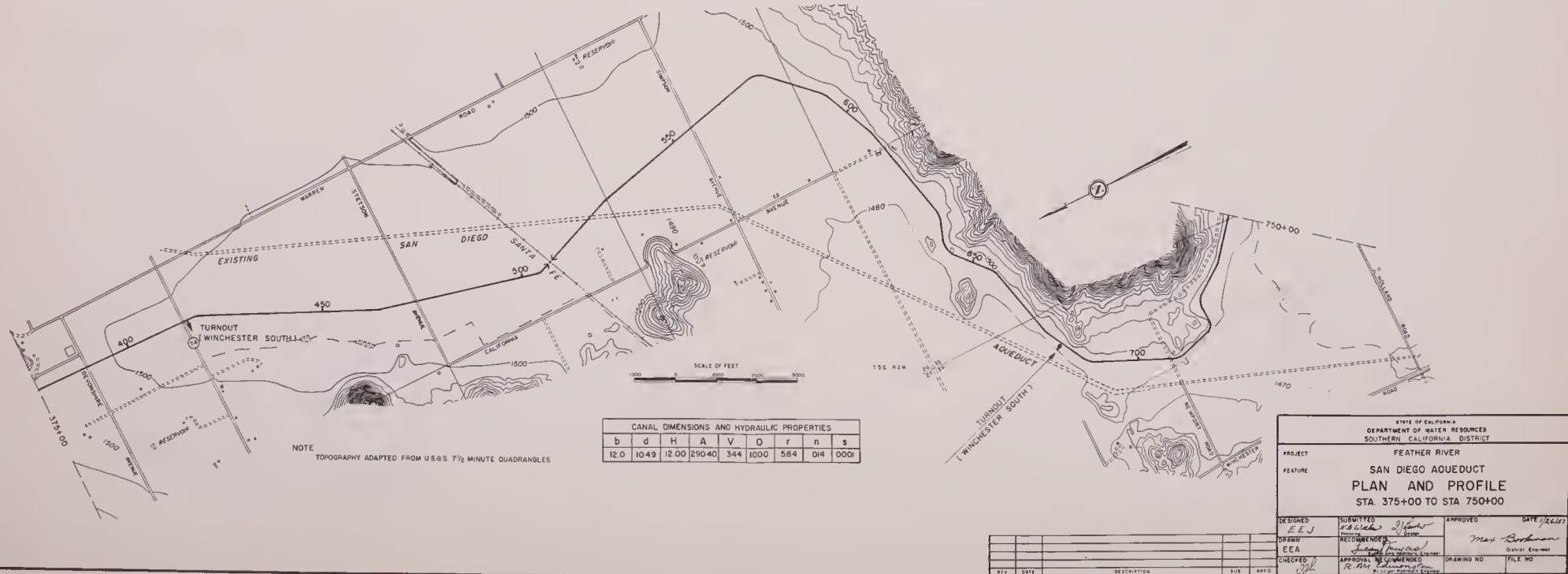
CANAL DIMENSIONS AND HYDRAULIC PROPERTIES									
b	d	H	A	V	D	r	n	s	
12.0	10.49	12.00	29.94	3.44	1000	5.84	0.14	0.001	

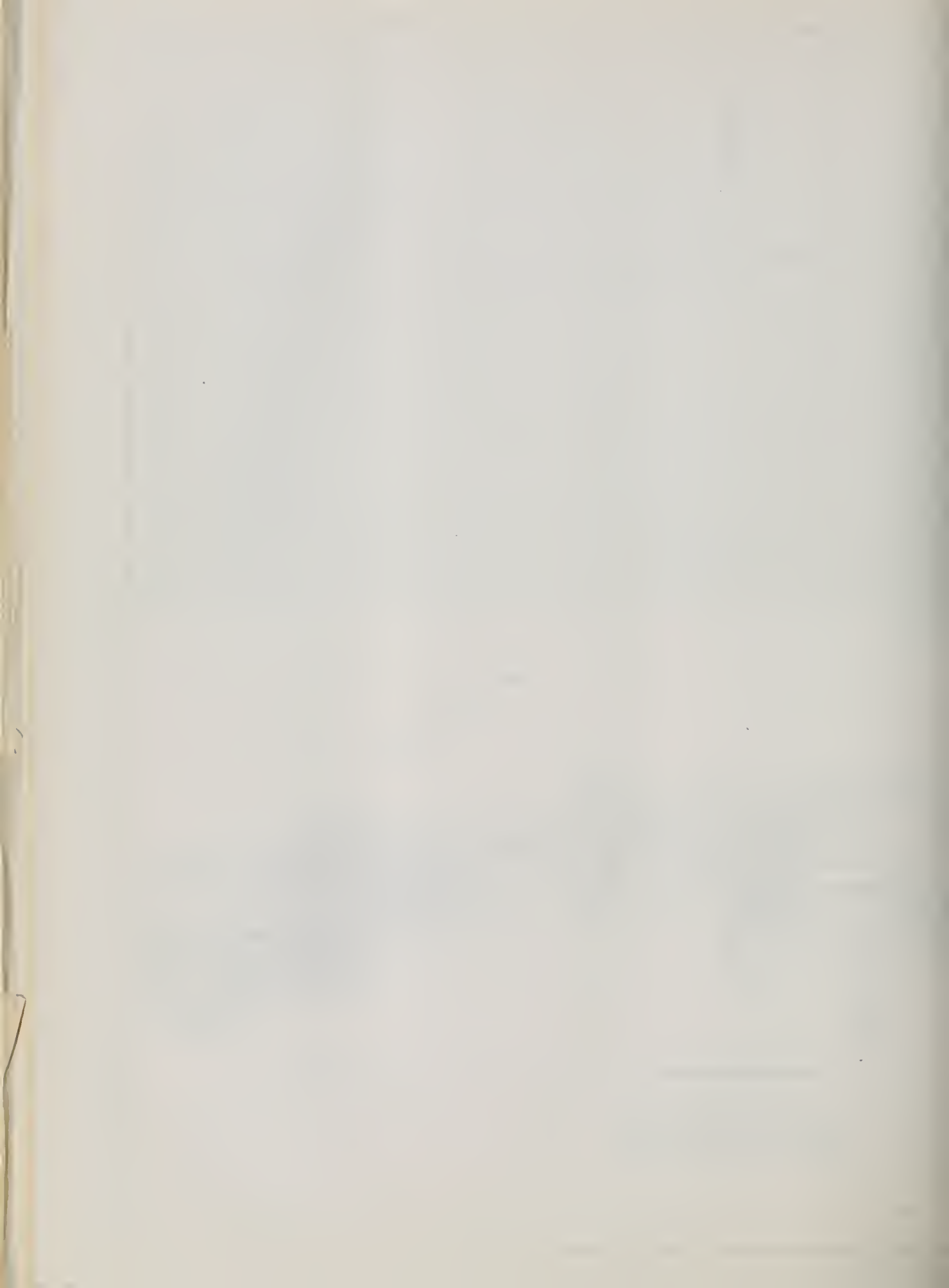


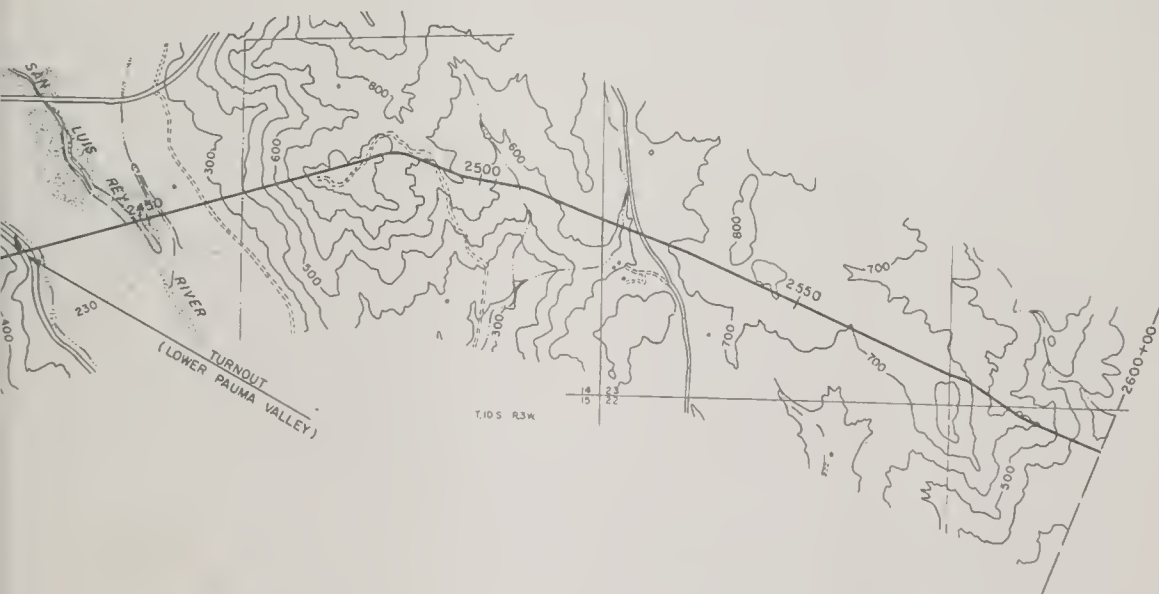
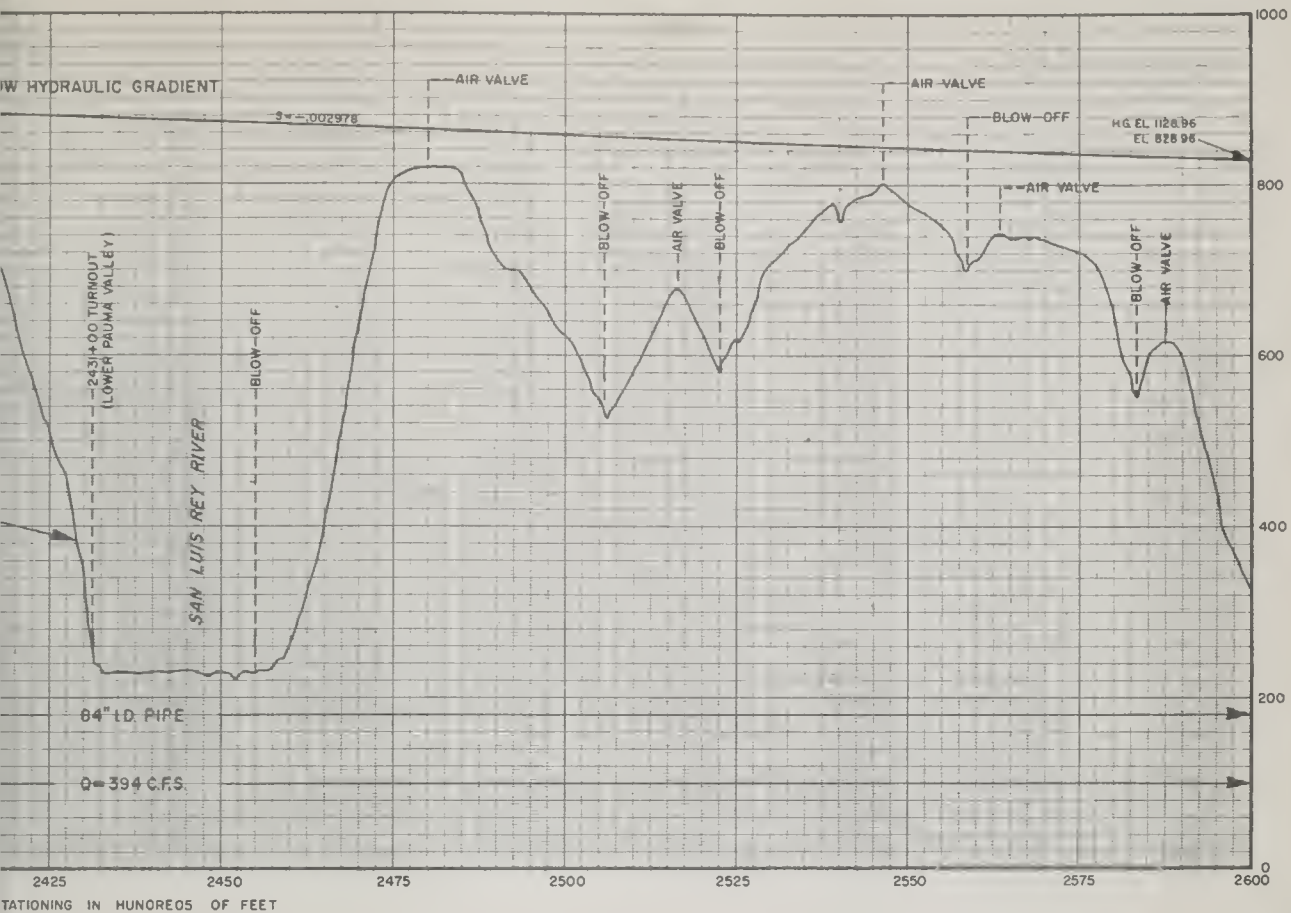
STATE OF CALIFORNIA DEPARTMENT OF WATER RESOURCES SOUTHERN CALIFORNIA DISTRICT			
PROJECT FEATHER RIVER			
FEATURE SAN DIEGO AQUEDUCT PLAN AND PROFILE STA 0+00 TO STA 375+00			
DESIGNED E.E.A.	SUBMITTED 10/10/67	APPROVED DATE 10/10/67	
DRAWN E.E.A.	CHECKED E.E.A.	APPROVED DATE 10/10/67	
CHECKED E.E.A.	APPROVED DATE 10/10/67	DRAWING NO.	FILE NO.

[illegible]







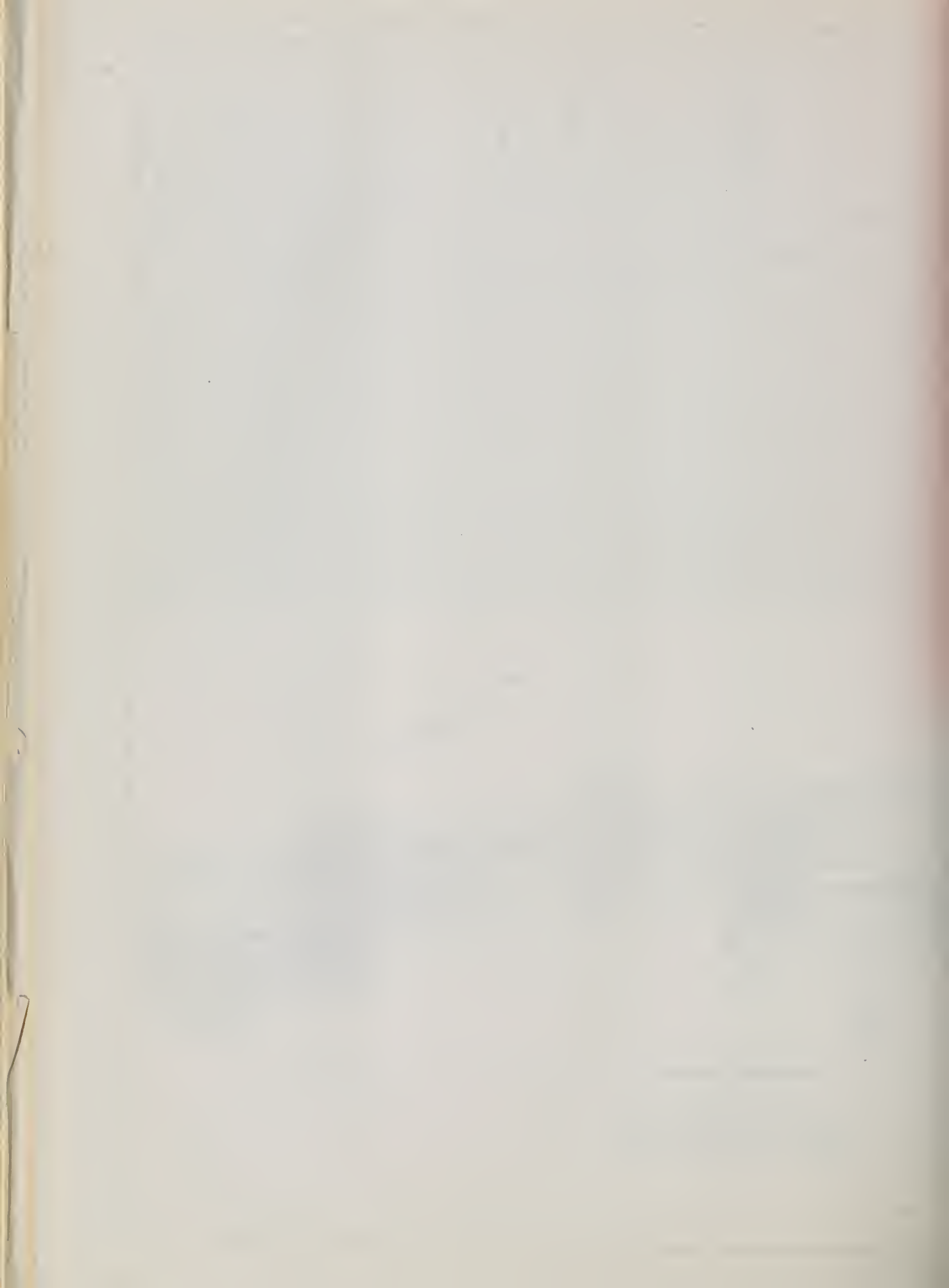


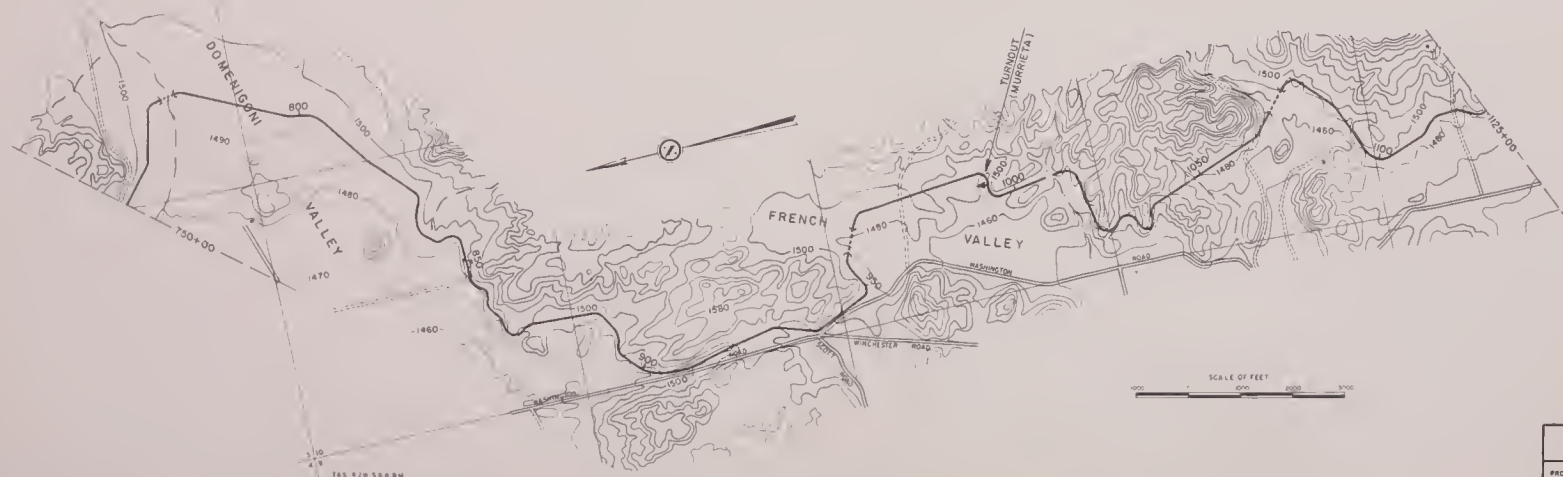
FEET
0 2000 3000

PROPERTIES		
n	r	s
0115	175	002978

REV	DATE	DESCRIPTION	SUB	APP'D

STATE OF CALIFORNIA DEPARTMENT OF WATER RESOURCES SOUTHERN CALIFORNIA DISTRICT			
PROJECT FEATHER RIVER			
FEATURE SAN DIEGO AQUEDUCT PLAN AND PROFILE STA. 2225+00 TO STA 2600+00			
DESIGNED EES	SUBMITTED J. B. Wilbur	APPROVED DATE 1/24/67	
DRAWN JPB	RECOMMENDED J. B. Wilbur	Max Bookman District Engineer	
CHECKED J. B. Wilbur	APPROVAL RECOMMENDED R. M. Edwards	DRAWING NO.	FILE NO.

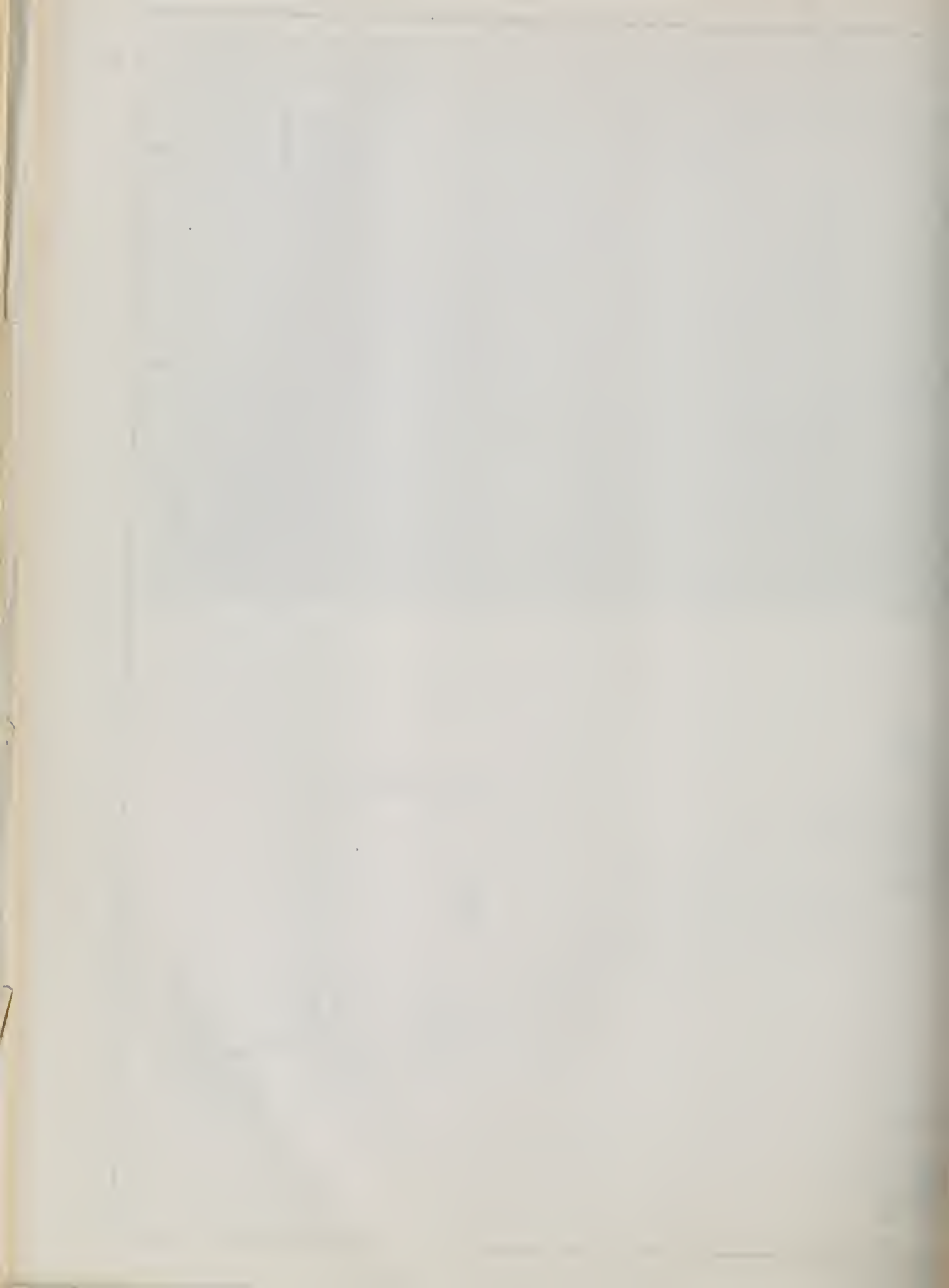


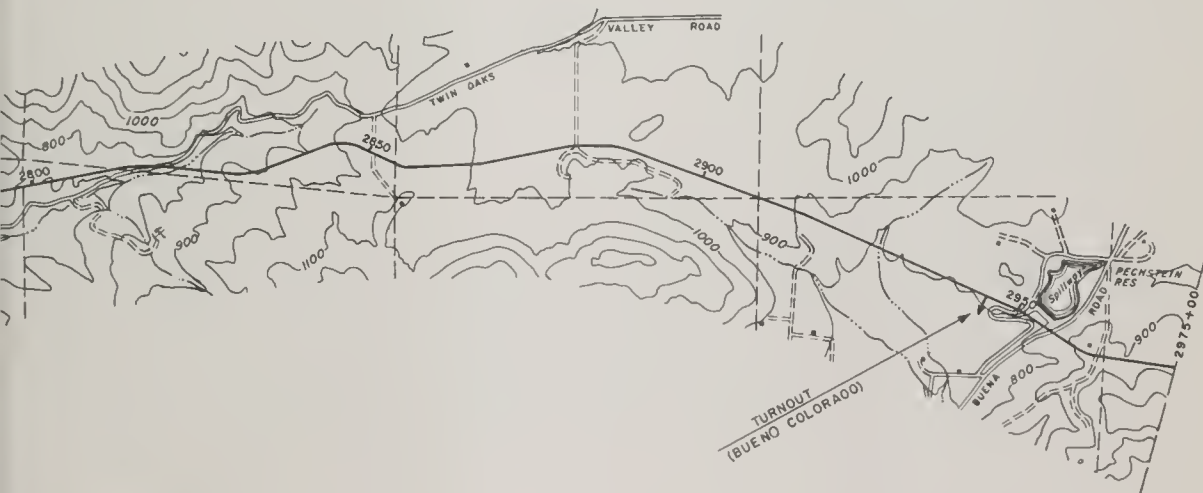
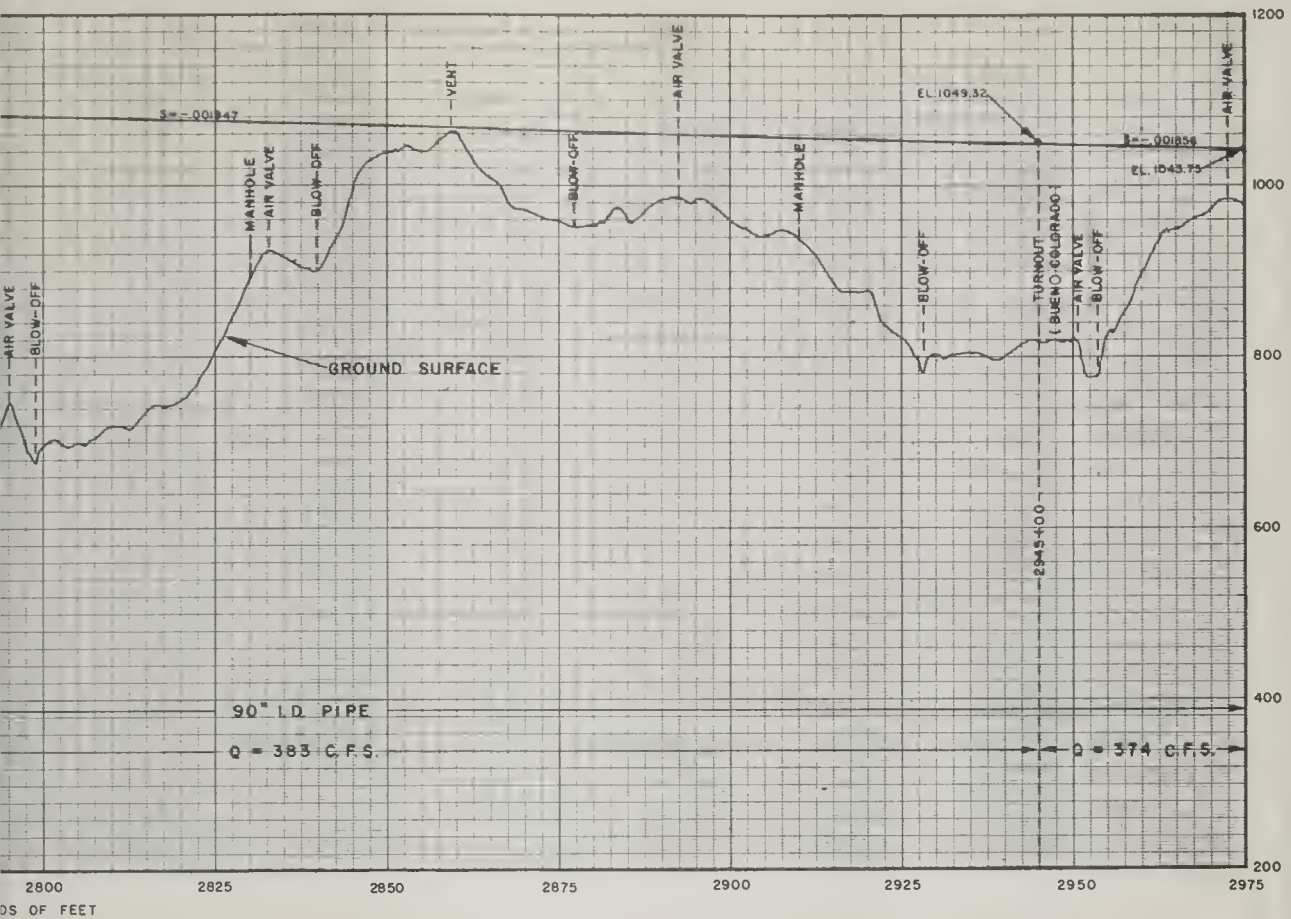


NOTE
TOPOGRAPHY ADAPTED FROM USGS 7½ MINUTE QUADRANGLES

CANAL DIMENSIONS AND HYDRAULIC PROPERTIES								
b	d	H	A	V	Q	r	n	s
120	10.49	12.00	290.94	3.44	1000	5.84	0.14	0.001

STATE OF CALIFORNIA					
DEPARTMENT OF WATER RESOURCES					
SOUTHERN CALIFORNIA DISTRICT					
PROJECT FEATHER RIVER					
STAN DIEGO AQUEDUCT					
PLAN AND PROFILE					
STA. 750+00 TO STA H25+00					
DESIGNED <i>EJL</i>	SUBMITTAL <i>P. Schmitt</i> <i>W. L. Smith</i>	APPROVED	DATE <i>1/6/58</i>		
DRAWN	RECOMMENDED BY	<i>M. A. Thompson</i>			
CHECKED <i>EEA</i>	FOR THE DIRECTOR <i>R. M. Edwards</i> REGIONAL ENGINEER				
CHECKED	DATE	DRAWING NO.	FILE NO.		



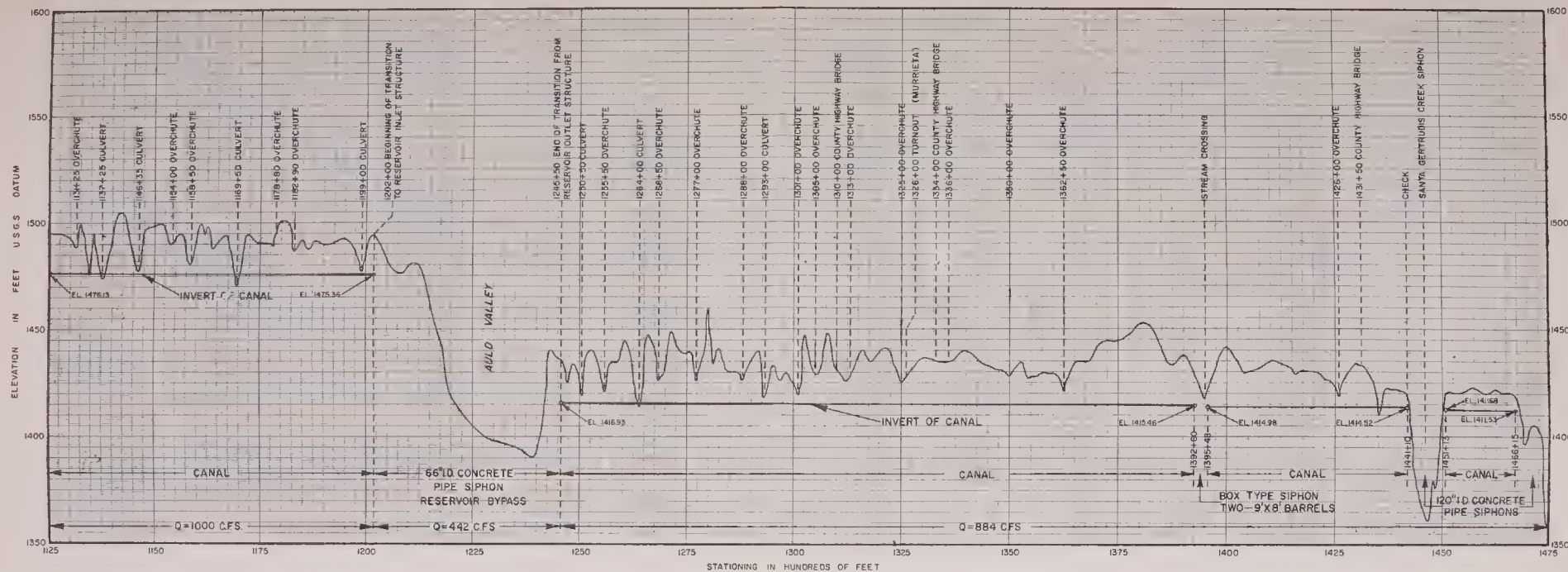


2000 3000

PROPERTIES		
n	r	s
0115	1.75	.002978
0115	1.875	.001947
0115	1.875	.001856

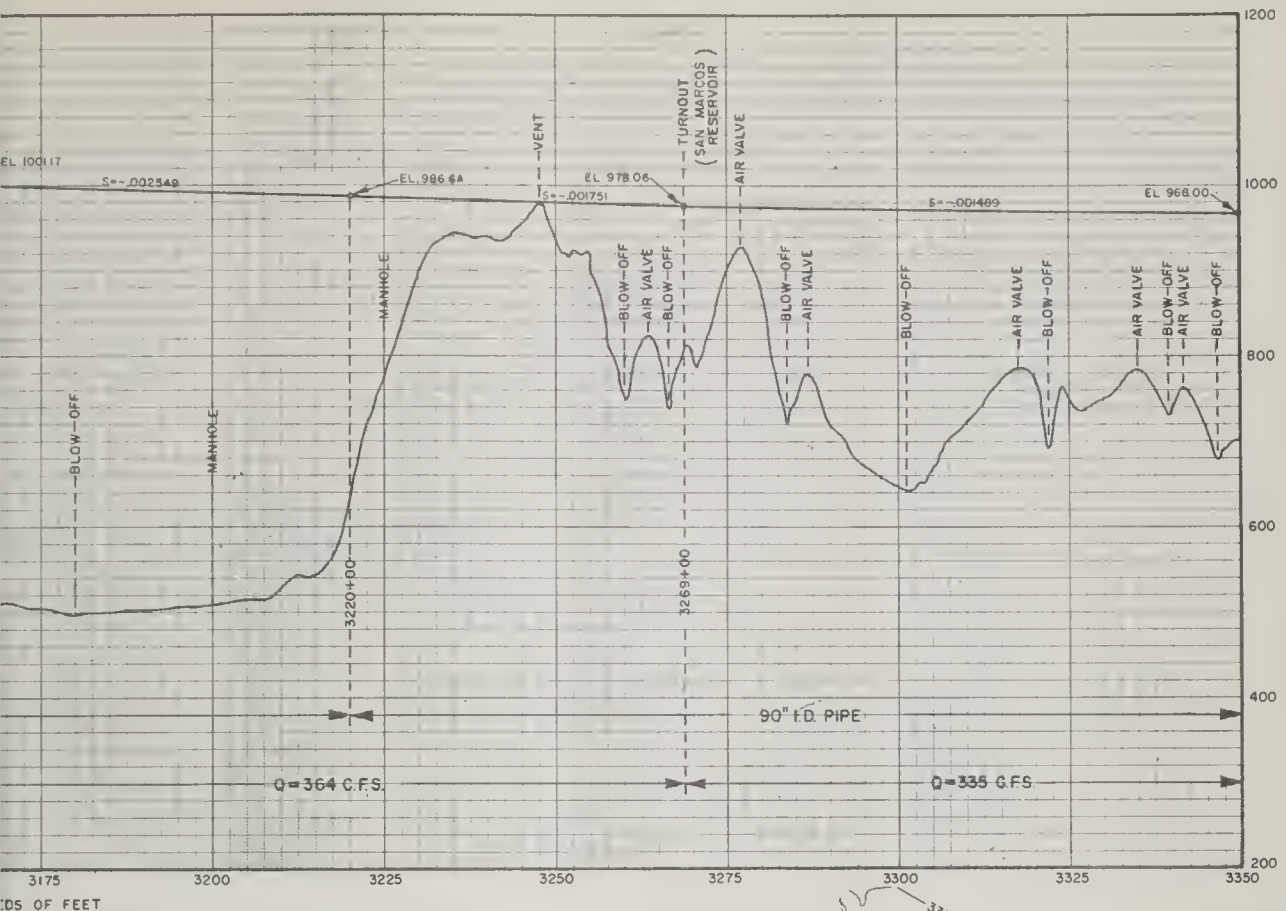
REV	DATE	DESCRIPTION	SUB	APP'D

STATE OF CALIFORNIA DEPARTMENT OF WATER RESOURCES SOUTHERN CALIFORNIA DISTRICT			
PROJECT FEATHER RIVER			
FEATURE SAN DIEGO AQUEDUCT PLAN AND PROFILE STA. 2600+00 TO STA. 2975+00			
DESIGNED EEJ	SUBMITTED N. A. Williams RECOMMENDED J. H. Williams	APPROVED Max Bordenman District Engineer	DATE 1/24/67
DRAWN LSG	CHECKED J. H. Williams	APPROVAL RECOMMENDED R. M. Williams Principal Engineer	DRAWING NO. FILE NO.



CANAL DIMENSIONS AND HYDRAULIC PROPERTIES									
b	d	H	A	V	Q	r	n	s	
120	10.49	12.00	290.40	3.44	1000	584	.014	.0001	
120	9.87	11.40	264.57	3.34	884	556	.014	.0001	

STATE OF CALIFORNIA DEPARTMENT OF WATER RESOURCES SOUTHERN CALIFORNIA DISTRICT	
PROJECT FEATHER RIVER	
SAN DIEGO AQUEDUCT PLAN AND PROFILE STA 1125+00 TO STA 1475+00	
DESIGNED E.F.J.	CHECKED R. B. B. B.
DRAWN J.P.B. & E.E.A.	APPROVED MAY 1967
CHECKED J.P.B.	FILE NO.

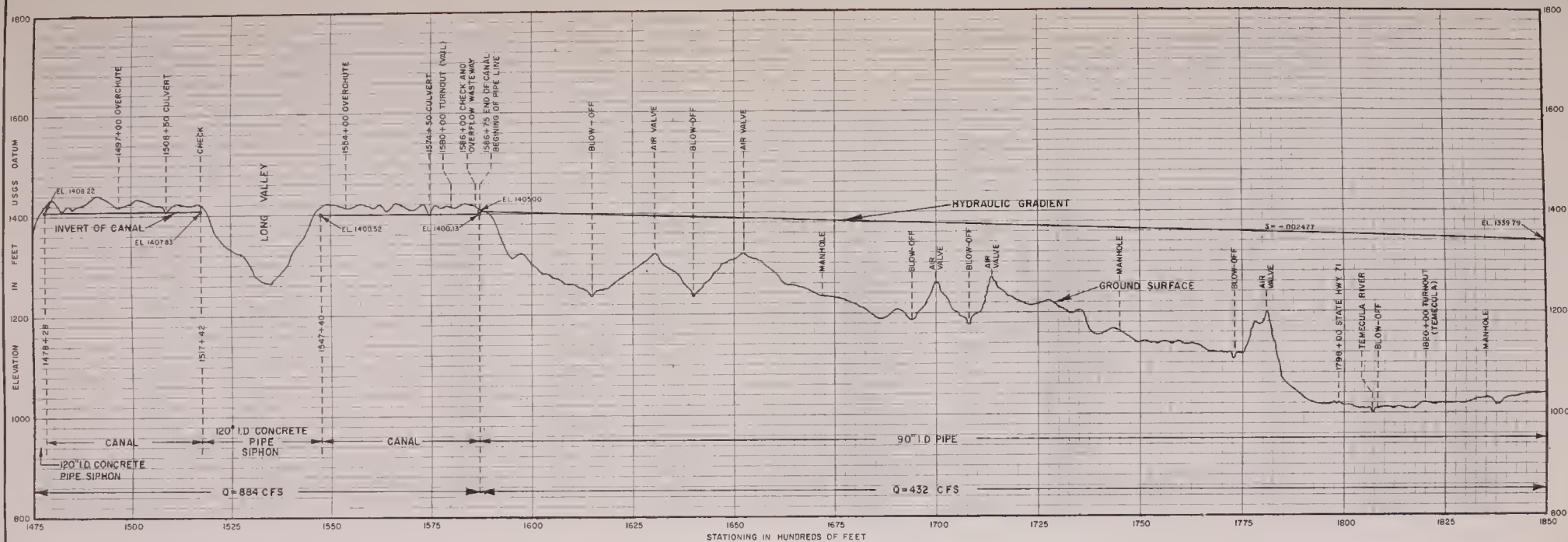


HYDRAULIC PROPERTIES							
DIA.	Q	A	V	n	r	s	
90"	374	4418	8.47	0.115	1.875	.001856	
84"	374	38.48	9.72	0.115	1.750	.002683	
84"	364	38.48	9.46	0.115	1.750	.002549	
90"	364	4418	8.24	0.115	1.875	.001751	
90"	335	4418	7.58	0.115	1.875	.001489	

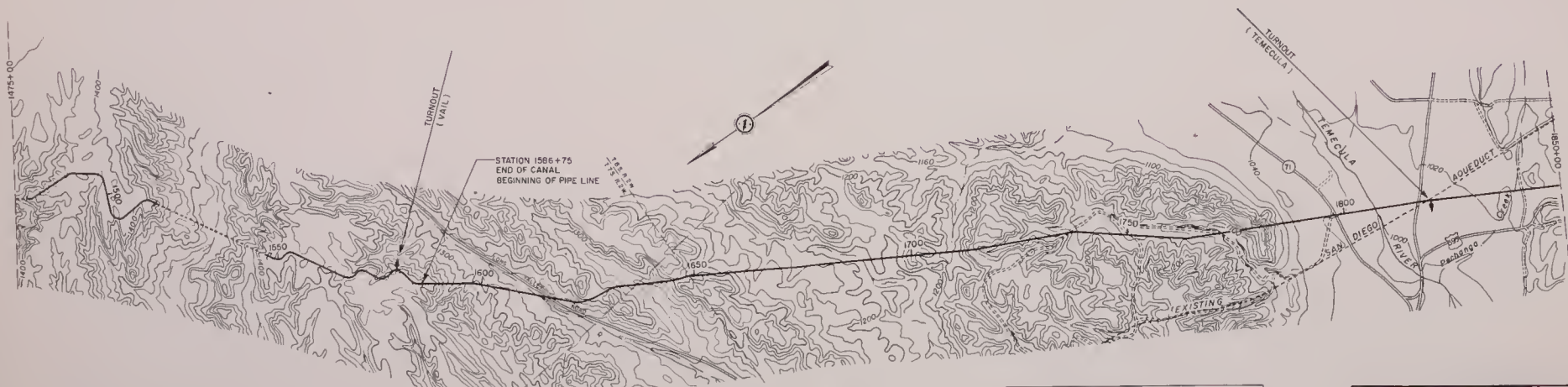


STATE OF CALIFORNIA DEPARTMENT OF WATER RESOURCES SOUTHERN CALIFORNIA DISTRICT			
PROJECT FEATHER RIVER		DATE 1/14/57	
FEATURE SAN DIEGO AQUEDUCT		District Engineer	
PLAN AND PROFILE STA 2975+00 TO STA. 3350+00		Max. Borkman	
DESIGNED E.E.J.	SUBMITTED R.B. Wilbur 2/1/57	APPROVED	
CHECKED JPB & RPB	RECOMMENDED R.M. Coleman	APPROVAL	
CHECKED 2/1/57	APPROVAL R.M. Coleman	DRAWING NO.	FILE NO.

REV	DATE	DESCRIPTION	SUB	APPD



NOTE CHANGE IN VERTICAL SCALE
FROM PRECEDING SHEET

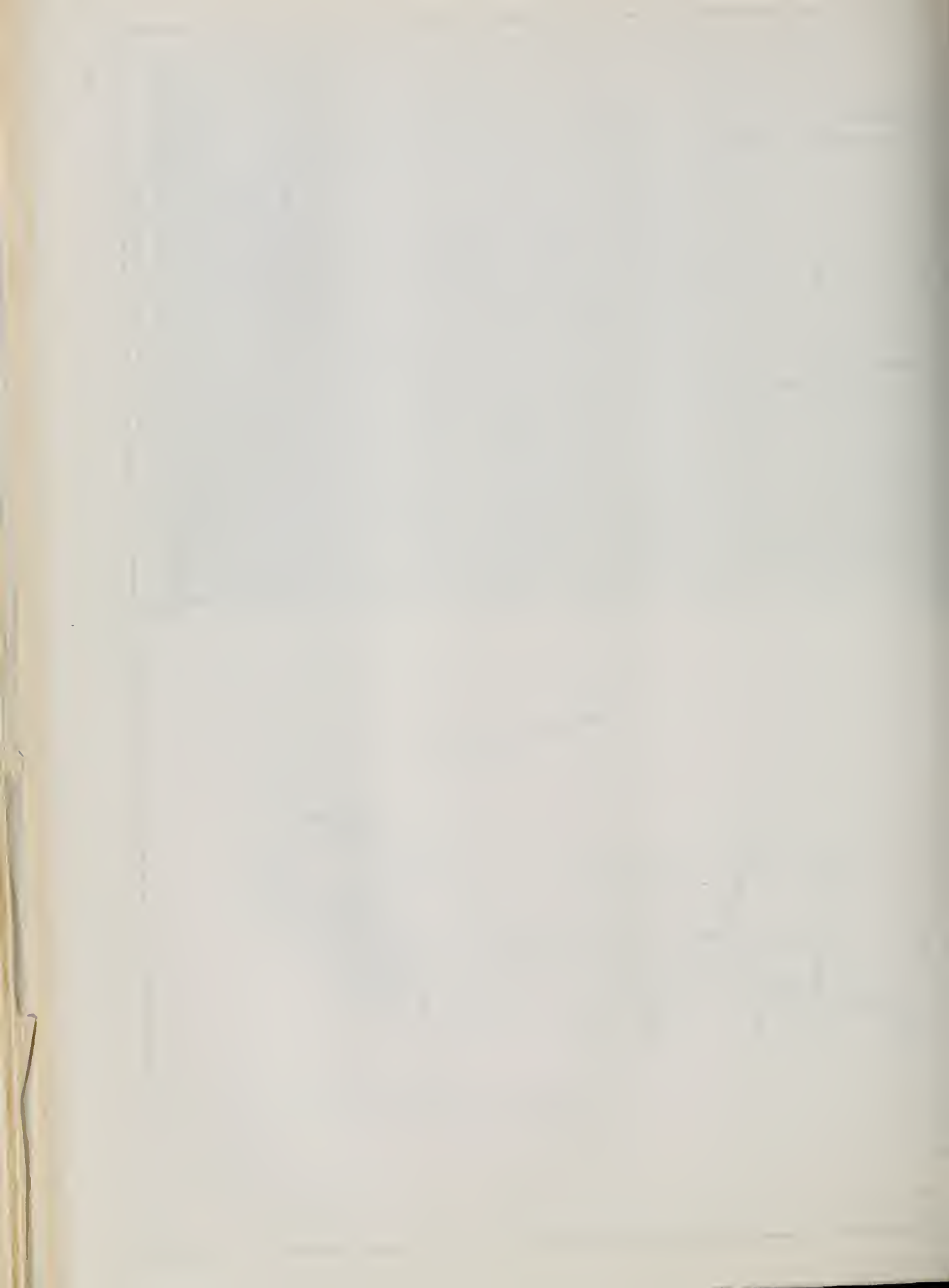


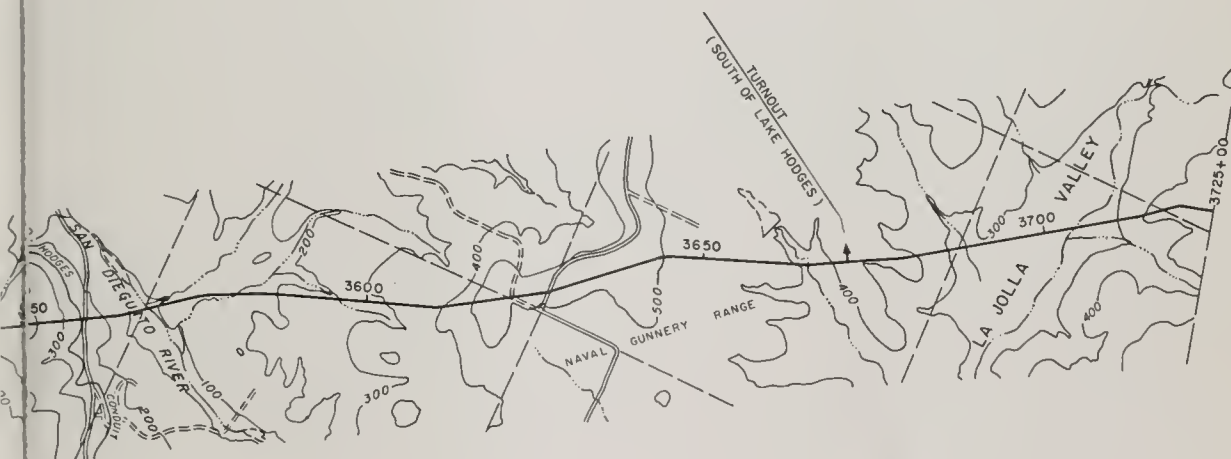
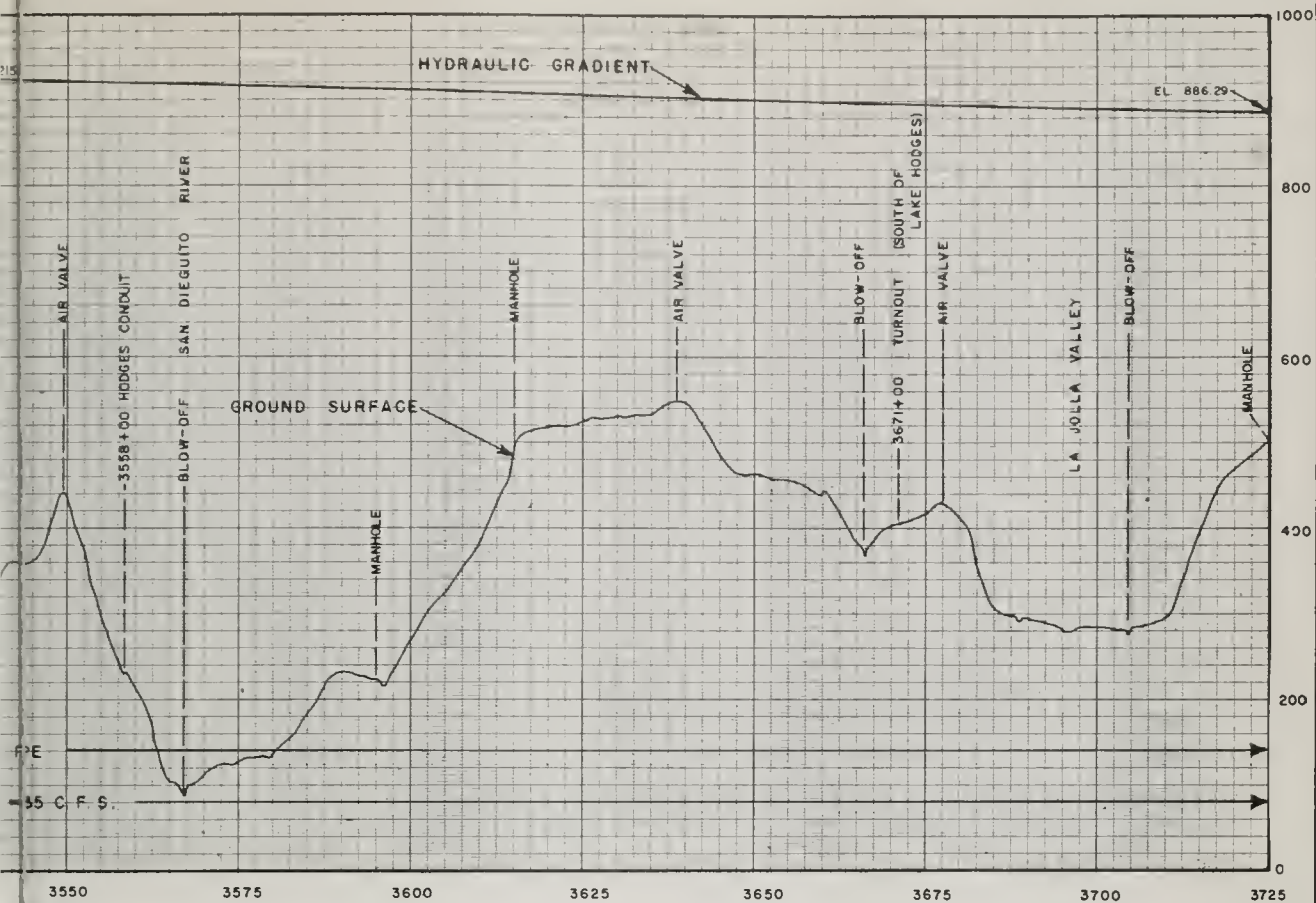
NOTE
TOPOGRAPHY ADAPTED FROM USGS 7 1/2 MINUTE QUADRANGLES

CANAL DIMENSIONS AND HYDRAULIC PROPERTIES									
b	d	H	A	V	Q	r	n	s	
120	987	11.40	26457	3.34	884	556	0.04	0.001	

PIPE LINE HYDRAULIC PROPERTIES						
DIA	Q	A	V	n	r	s
90"	432	4418	978	0.115	1825	0.02477

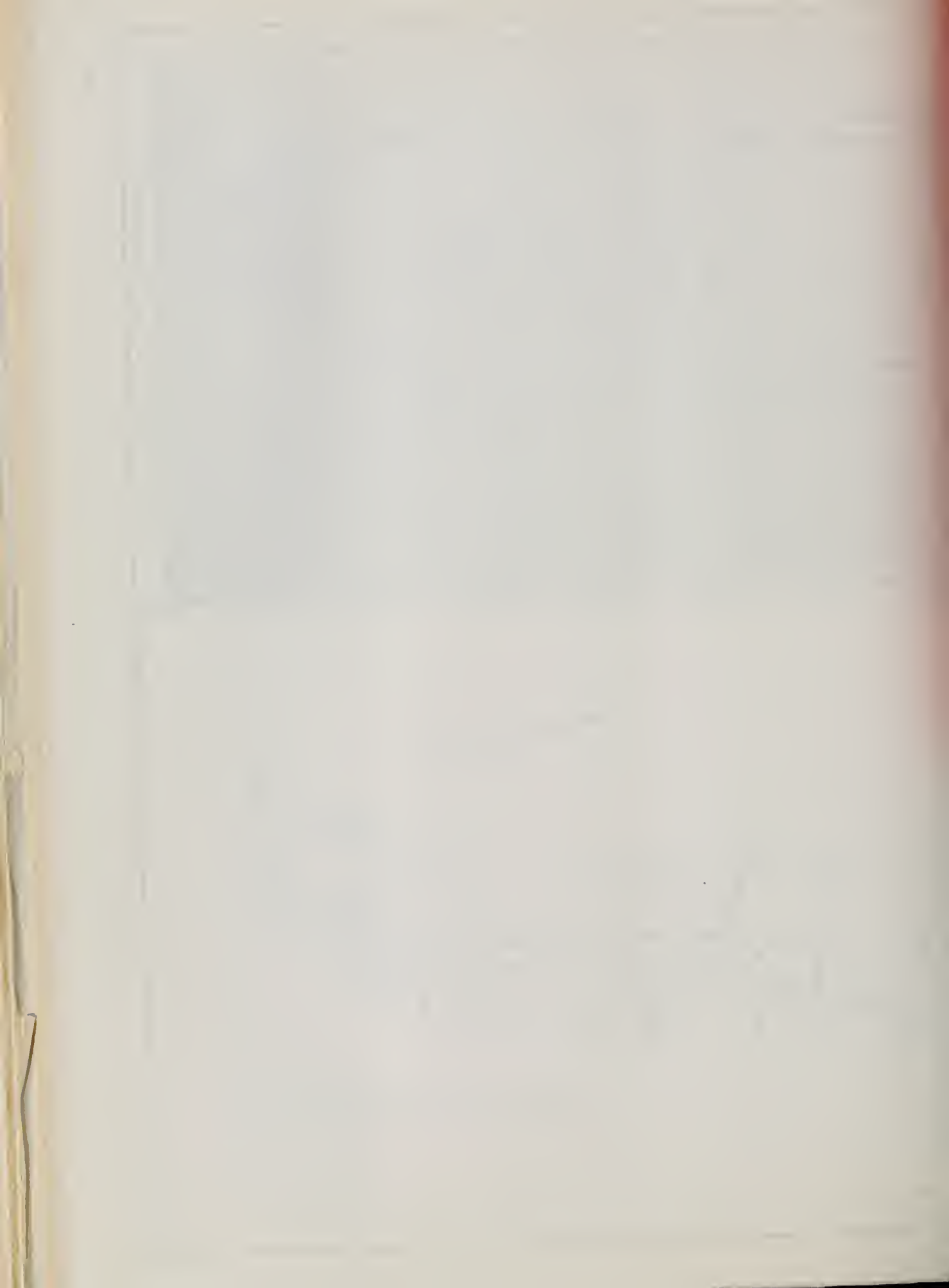
STATE OF CALIFORNIA DEPARTMENT OF WATER RESOURCES SOUTHERN CALIFORNIA DISTRICT	
PROJECT FEATHER RIVER	
FEATURE SAN DIEGO AQUEDUCT PLAN AND PROFILE STA 1475+00 TO STA 1850+00	
DESIGNED E.E.J.	APPROVED DATE 1/10/60 Max Bodman
DRAWN E.E.A.	RECOMMENDED DATE 1/10/60 Max Bodman
CHECKED C.A.H.	APPROVAL DATE 1/10/60 Max Bodman
DATE	FILE NO.

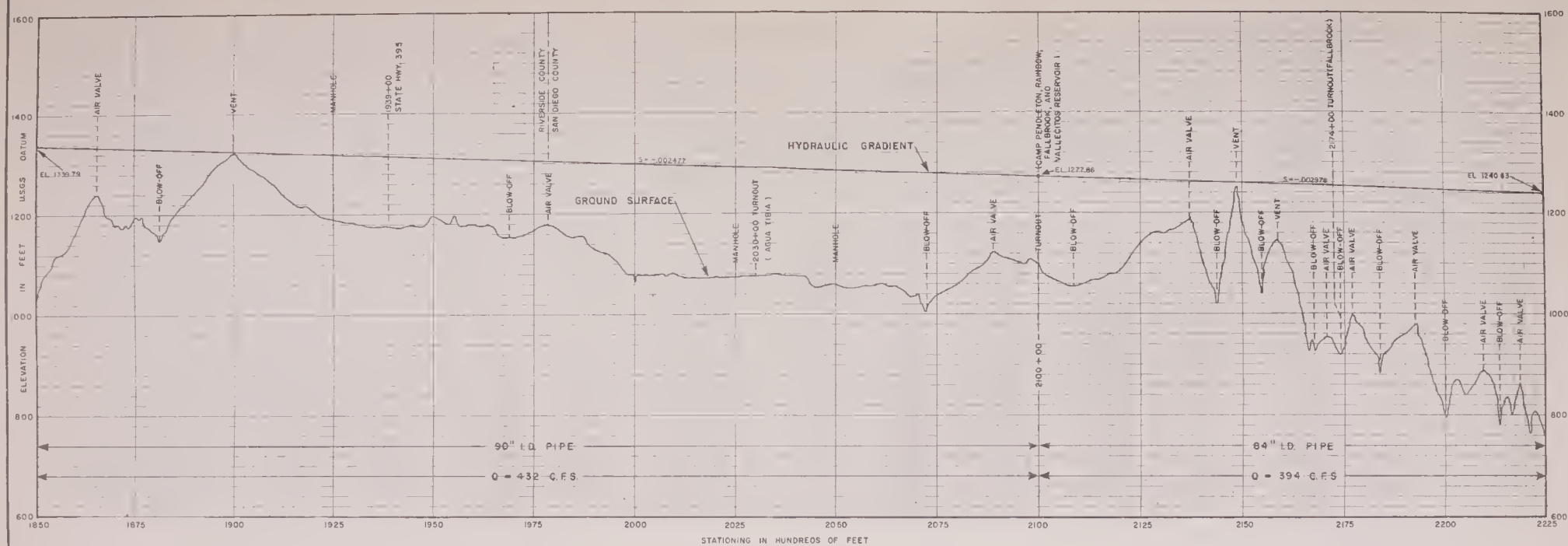




STATE OF CALIFORNIA DEPARTMENT OF WATER RESOURCES SOUTHERN CALIFORNIA DISTRICT			
PROJECT FEATHER RIVER		DATE 1/26/57	
FEATURE SAN DIEGO AQUEDUCT		APPROVED Max Bookman District Engineer	
DESIGNED E.E.J.		SUBMITTED R.B. Wilbur Checked RECOMMENDED R.M. Edmonston District Engineer	
DRAWN L.S.G.		DRAWING NO.	
CHECKED J.R.K.		FILE NO.	

REV	DATE	DESCRIPTION	SUB	APP



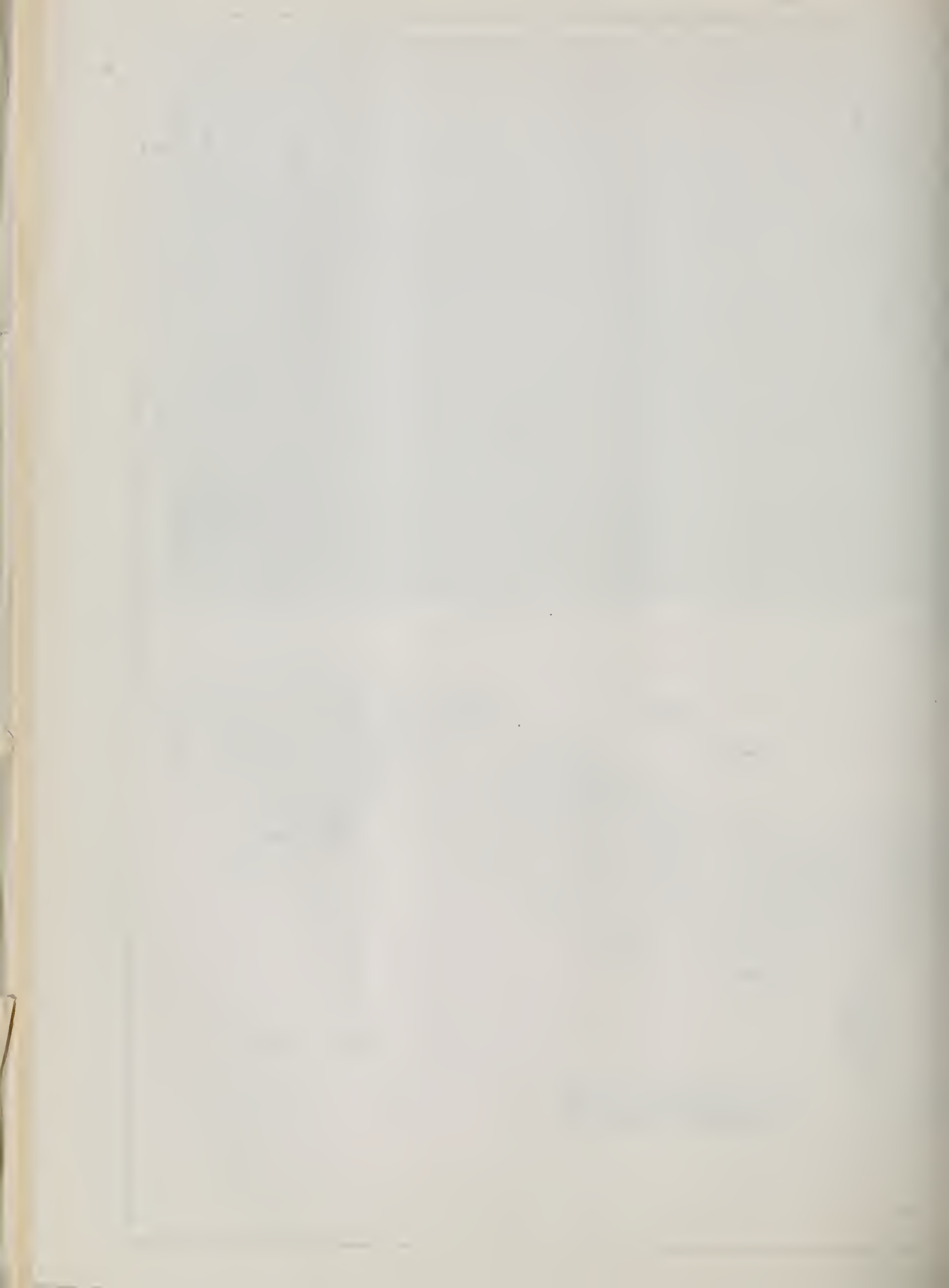


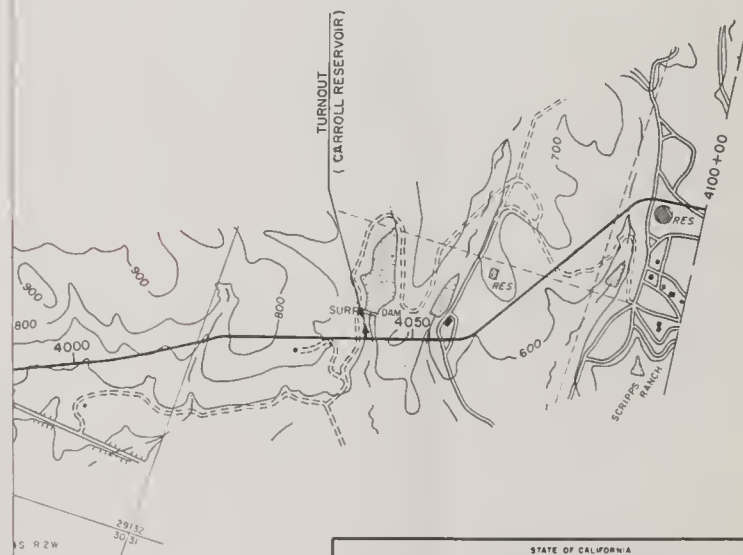
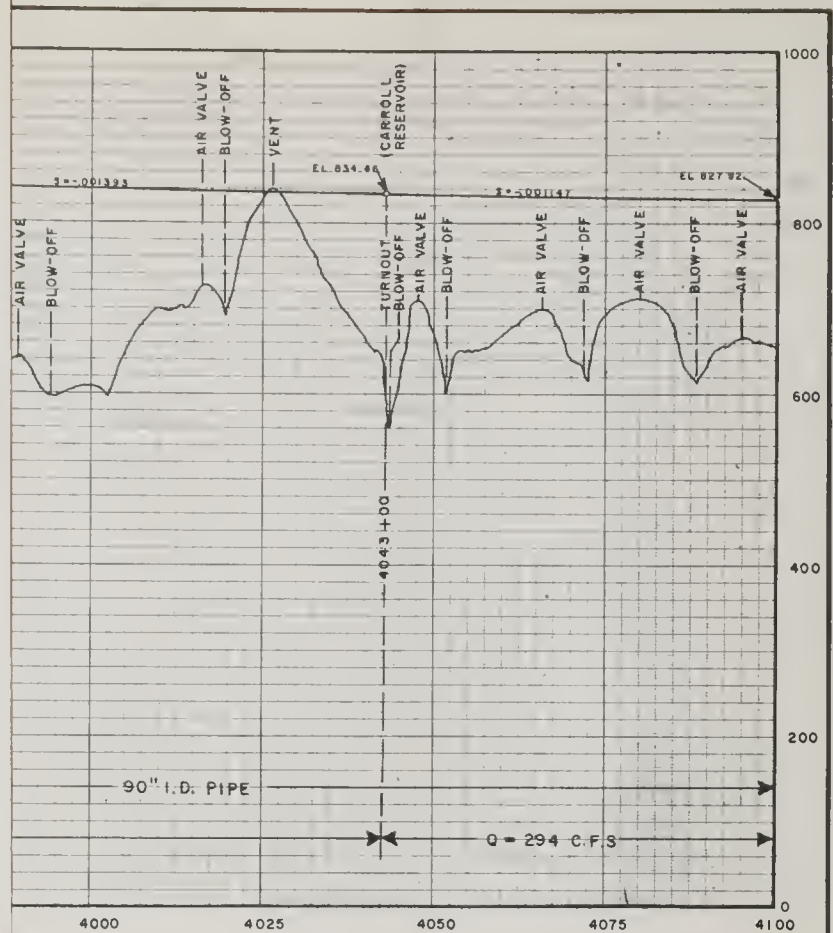
NOTE
TOPOGRAPHY ADAPTED FROM USGS 7 1/2 MINUTE QUADRANGLES



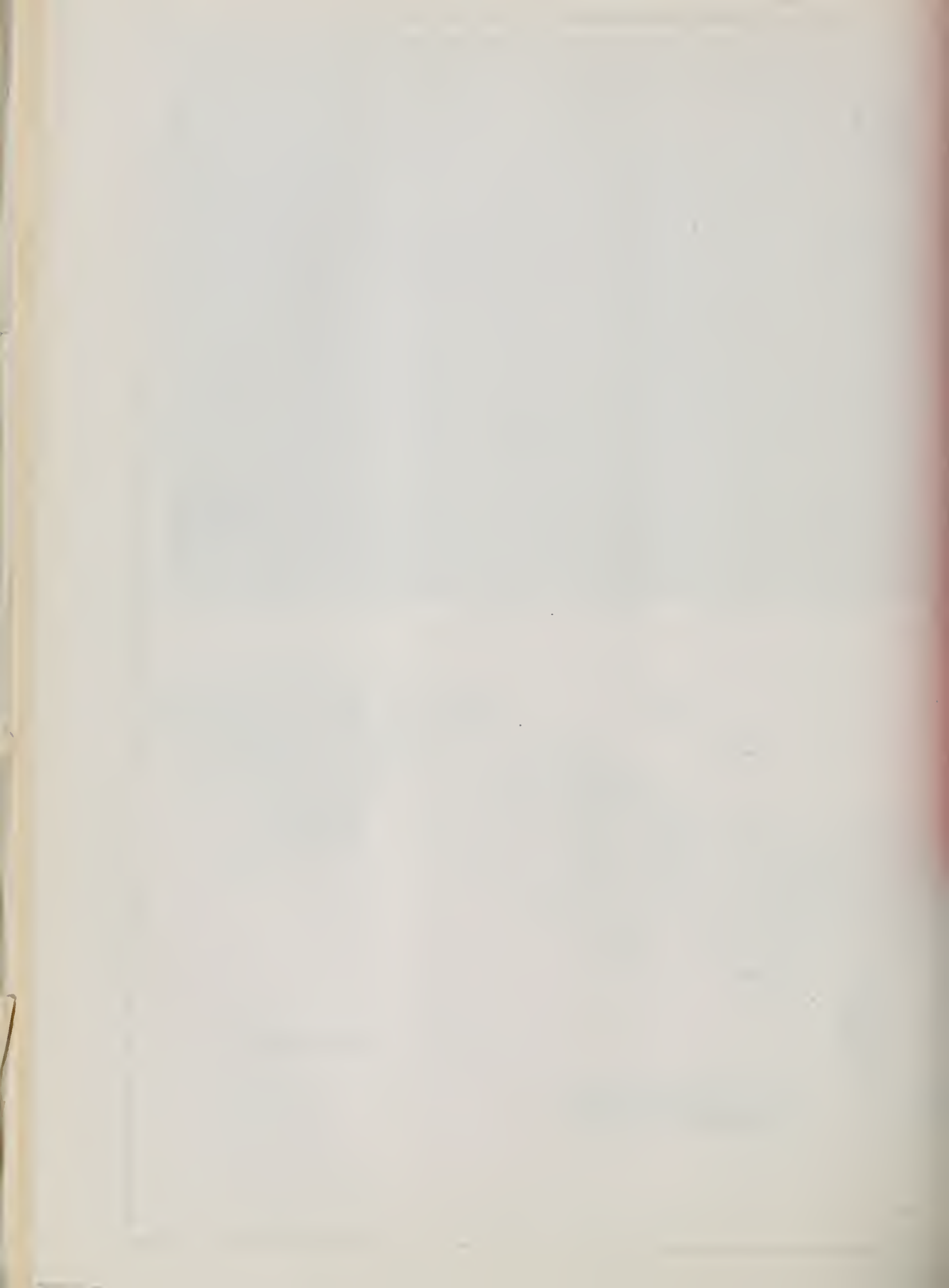
HYDRAULIC PROPERTIES							
DIA.	Q	A	V	n	r	s	
90"	432	44.8	9.78	0.15	1.675	0.02477	
84"	394	38.48	10.24	0.15	1.75	0.02978	

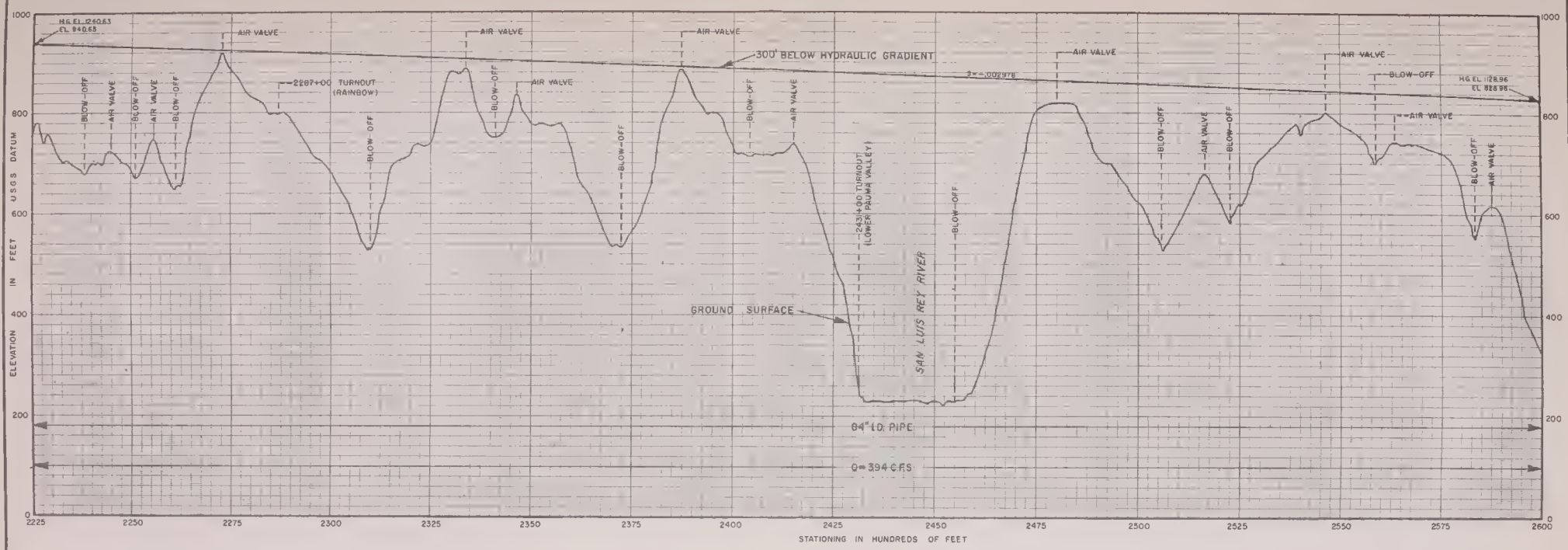
STATE OF CALIFORNIA DEPARTMENT OF WATER RESOURCES SOUTHERN CALIFORNIA DISTRICT			
PROJECT FEATHER RIVER			
FEATURE SAN DIEGO AQUEDUCT PLAN AND PROFILE STA. 1850+00 TO STA 2225+00			
DESIGNED E.E.A.	SUBMITTED E.E.A.	APPROVED E.E.A.	DATE 2/1/58
DRAWN E.E.A.	RECORDED E.E.A.	APPROVED E.E.A.	DATE 2/1/58
CHECKED E.E.A.	APPROVED E.E.A.	DRAWING NO.	FILE NO.





STATE OF CALIFORNIA DEPARTMENT OF WATER RESOURCES SOUTHERN CALIFORNIA DISTRICT			
PROJECT FEATHER RIVER		DATE 1/24/57	
FEATURE SAN DIEGO AQUEDUCT PLAN AND PROFILE STA 3725+00 TO STA 4100+00			
DESIGNED EEJ	SUBMITTED K. B. Wells 1/24/57	APPROVED Max Berkman District Engineer	
DRAWN JPB & LSG	RECOMMENDED James P. Wells 1/24/57	DRAWING NO	
CHECKED R. H. H. H.	APPROVAL RECOMMENDED R. H. H. H.	FILE NO	

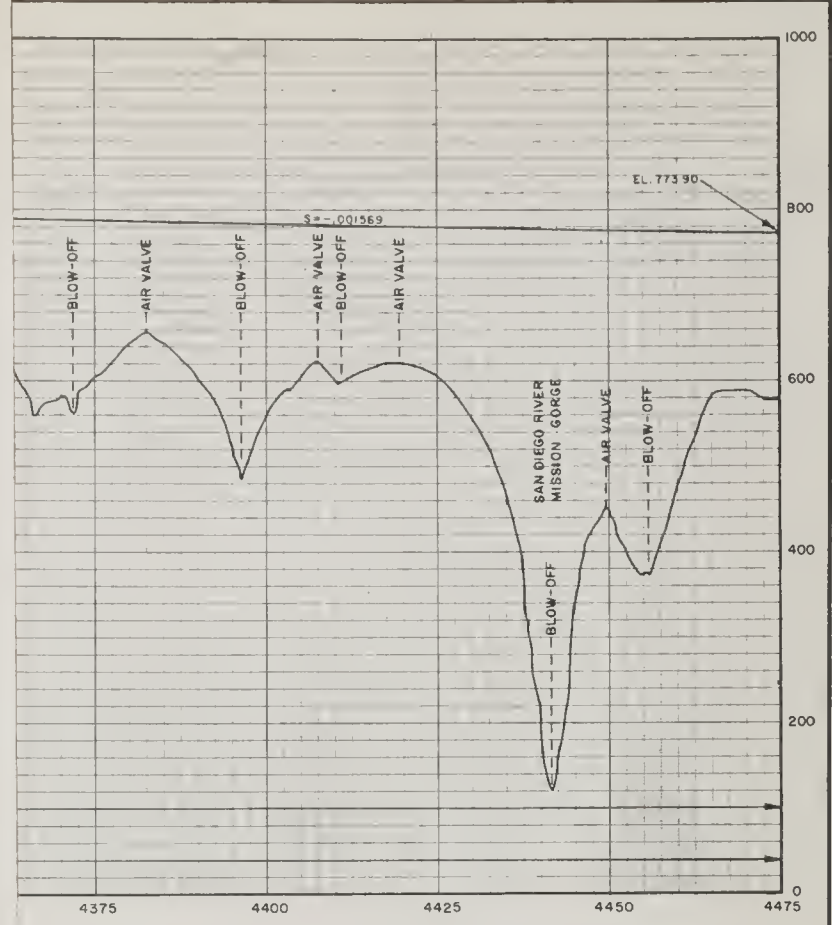




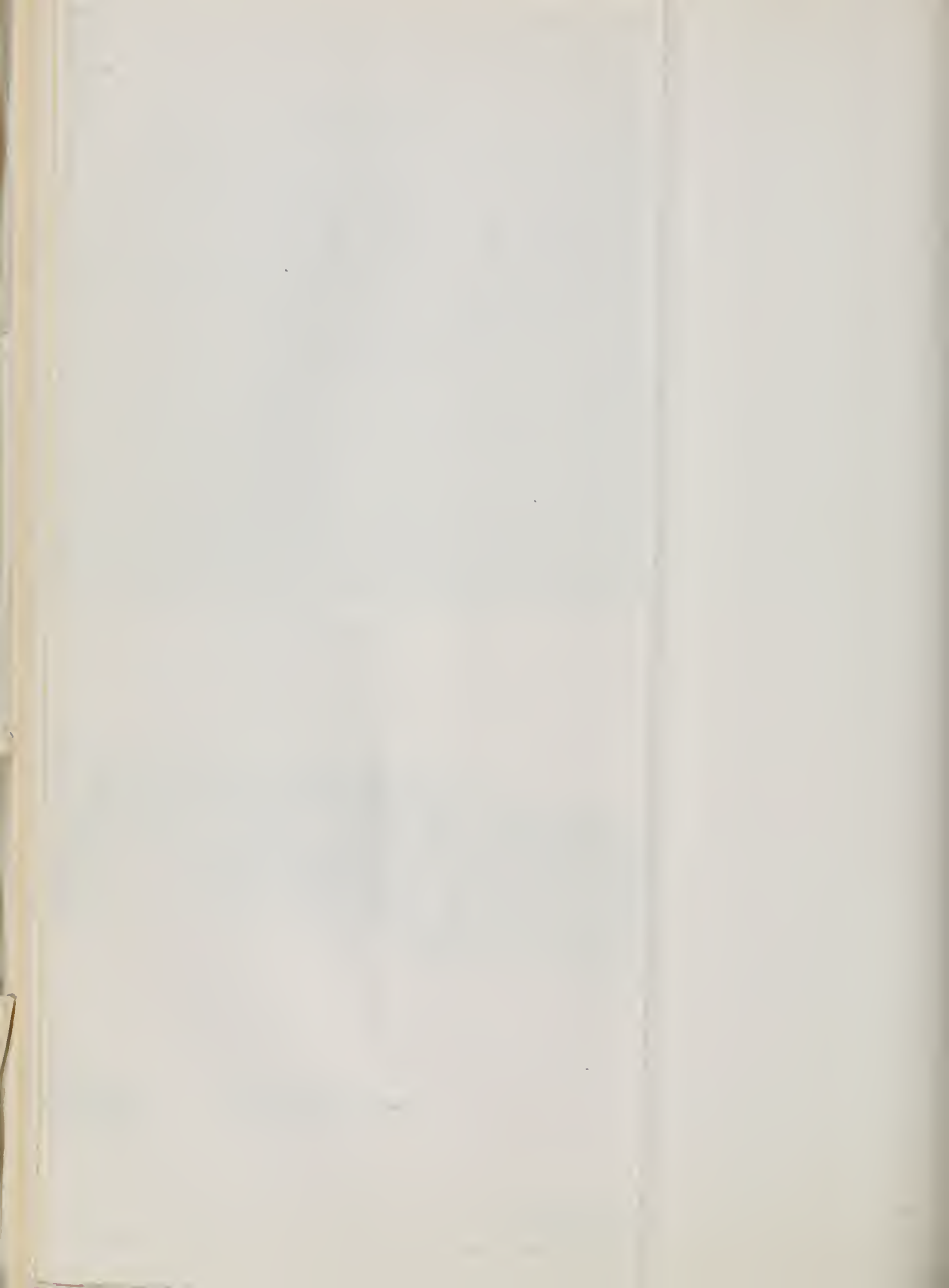
NOTE
TOPOGRAPHY ADAPTED FROM U.S.G.S. 7 1/2 MINUTE QUADRANGLES

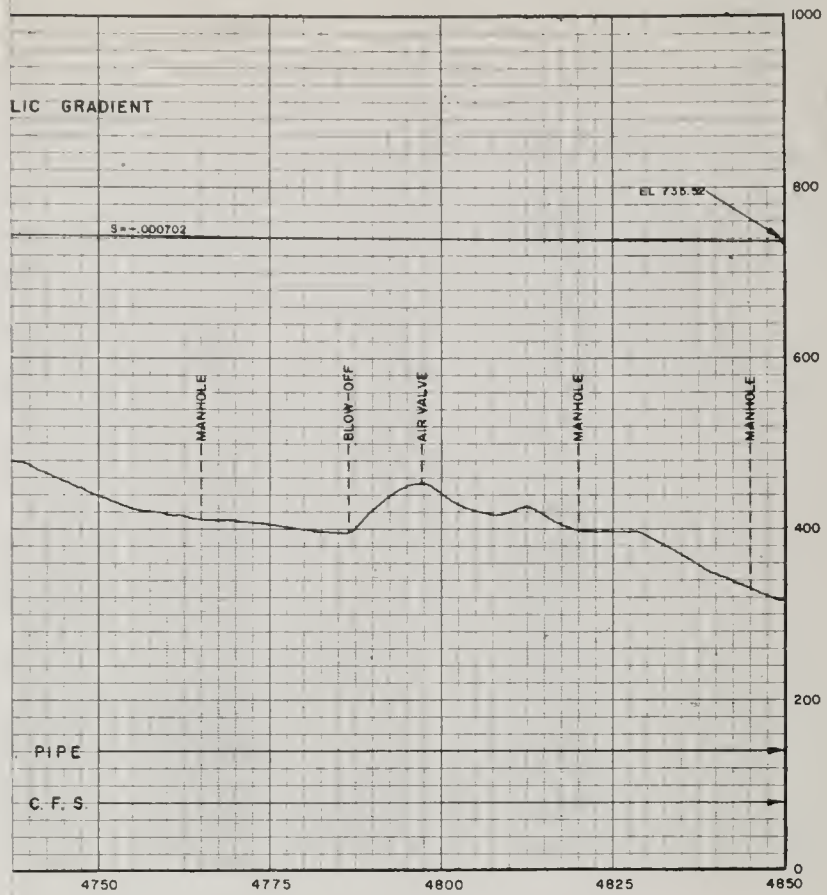
HYDRAULIC PROPERTIES						
DIA	Q	A	V	n	r	S
64"	394	3848	10.24	0.15	1.75	0.02978

STATE OF CALIFORNIA DEPARTMENT OF WATER RESOURCES SOUTHERN CALIFORNIA DISTRICT	
PROJECT FEATHER RIVER	
FEATURE SAN DIEGO AQUEDUCT PLAN AND PROFILE STA. 2225+00 TO STA 2600+00	
DESIGNED F. E. J.	CHECKED J. P. B.
APPROVED [Signature]	DATE 1/24/50
RECOMMENDED [Signature]	FILE NO.
CHECKED [Signature]	DRAWING NO.
REV	DATE
DESCRIPTION	SUB
APPD	



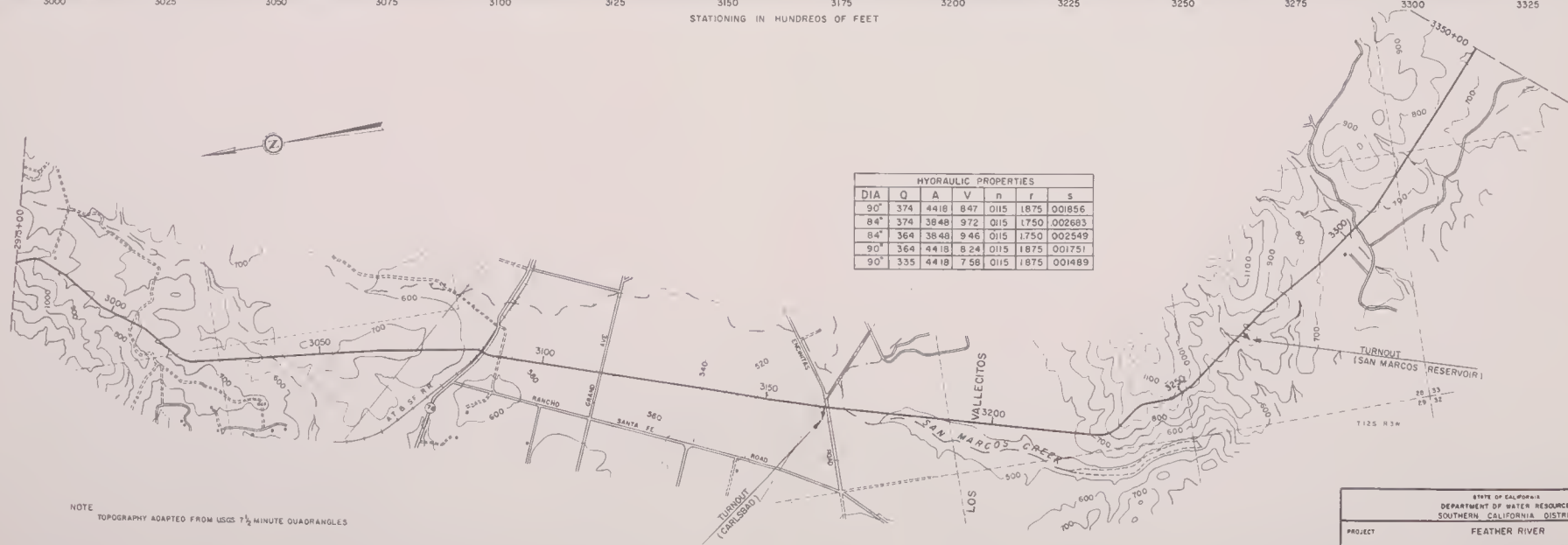
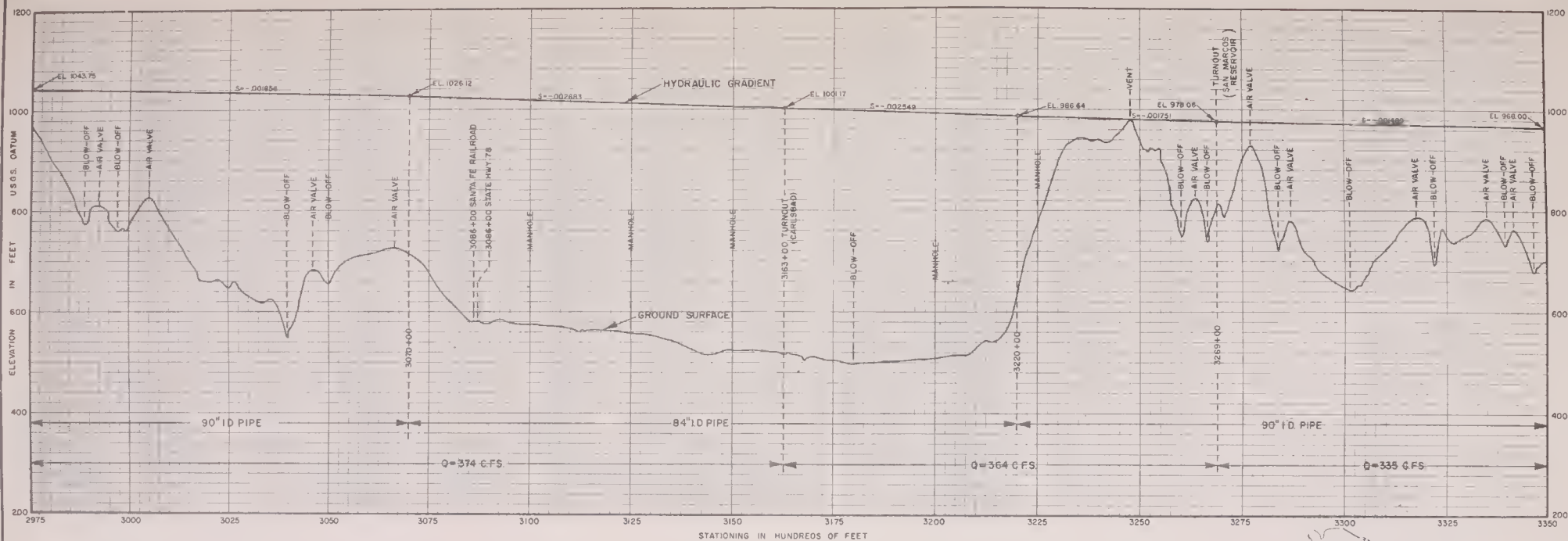
STATE OF CALIFORNIA DEPARTMENT OF WATER RESOURCES SOUTHERN CALIFORNIA DISTRICT			
PROJECT FEATHER RIVER			
FEATURE SAN DIEGO AQUEDUCT			
PLAN AND PROFILE STA. 4100+00 TO STA 4475+00			
DESIGNED EEJ	SUBMITTED K.B. Wilber	APPROVED Max Erdman	DATE 1/24/47
DRAWN LSG & RPB	RECOMMENDED J. M. Edwards	District Engineer	
CHECKED J. M. Edwards	APPROVAL RECOMMENDATION R. M. Edwards	DRAWING NO	FILE NO
DESCRIPTION		SUB	APPD





STATE OF CALIFORNIA DEPARTMENT OF WATER RESOURCES SOUTHERN CALIFORNIA DISTRICT			
PROJECT FEATHER RIVER			
FEATURE SAN DIEGO AQUEDUCT			
PLAN AND PROFILE STA 4475+00 TO STA 4850+00			
DESIGNED EEJ	SUBMITTED A. B. Wicks RECOMMENDED J. H. Wicks	APPROVED Max R. Korman	DATE 1/24/47
DRAWN JPB B RPB	CHECKED R. M. Edmonstone	DRAWING NO.	FILE NO.
DESCRIPTION SUB APPD			

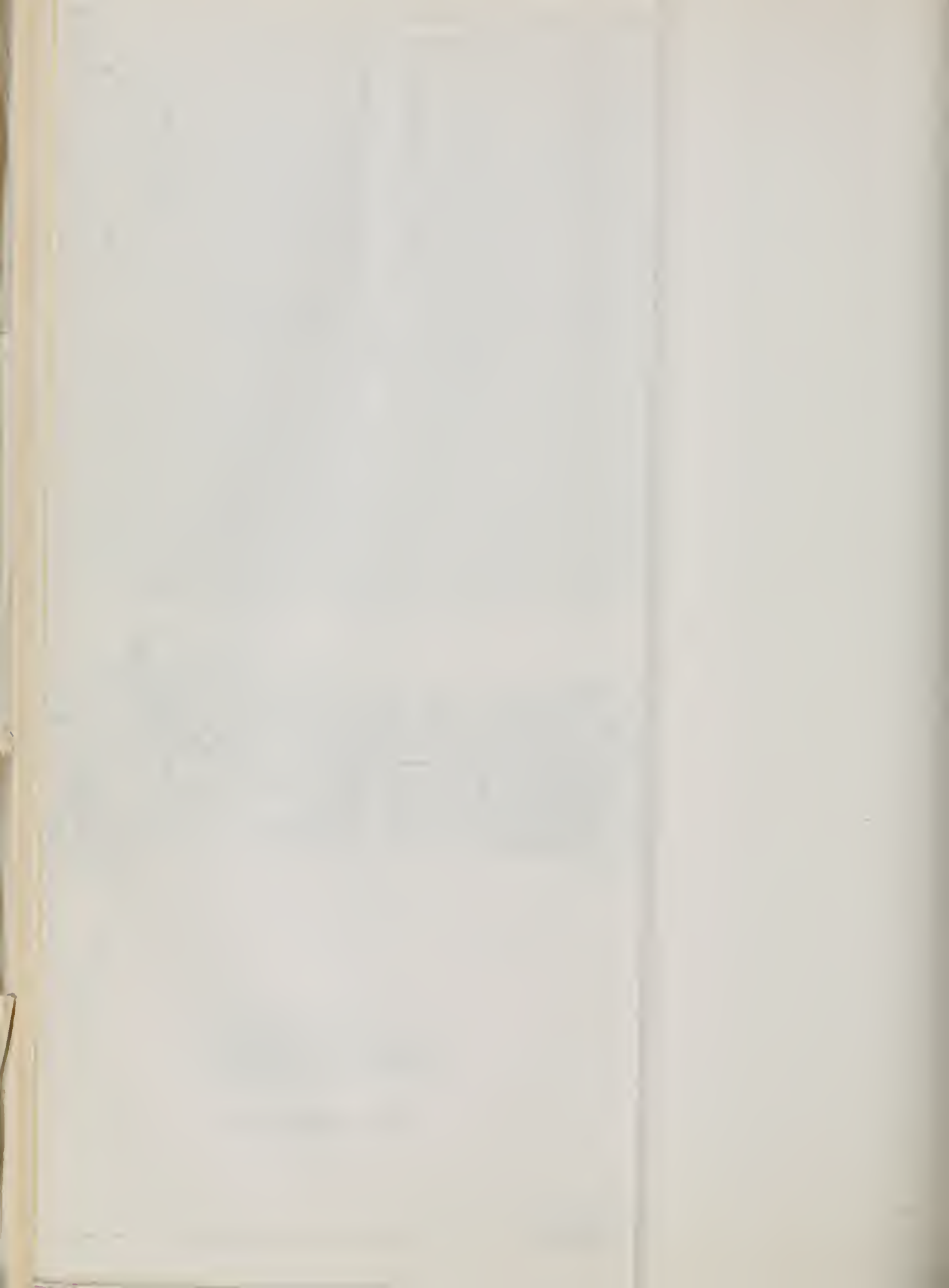


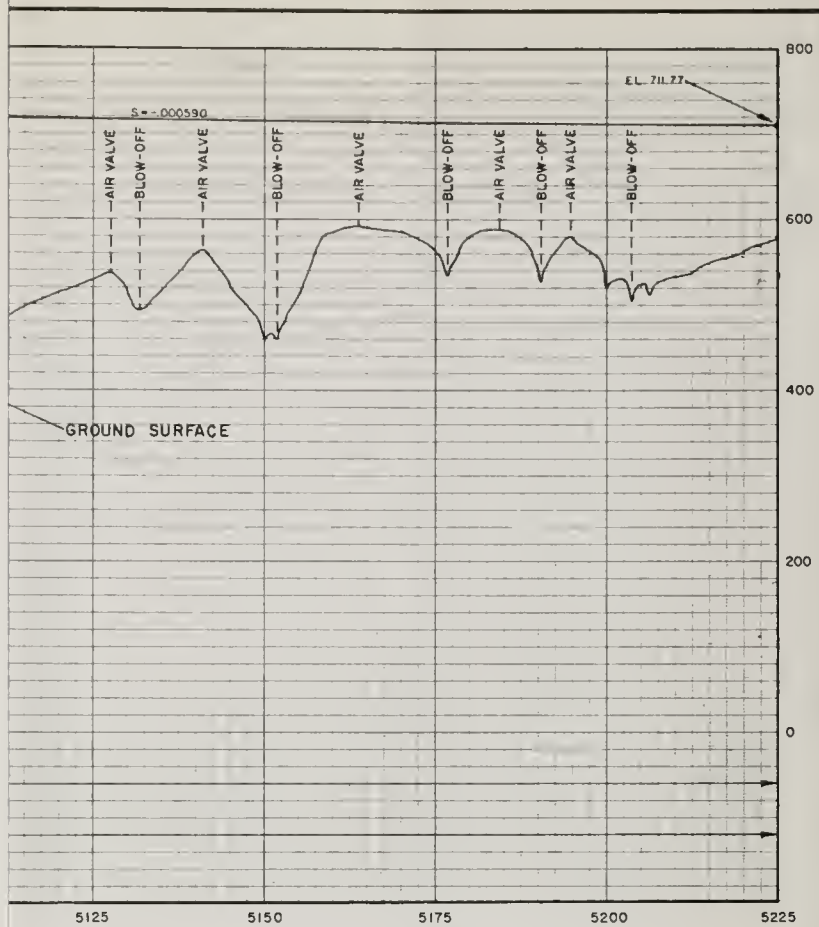


HYDRAULIC PROPERTIES									
DIA	Q	A	V	n	r	f	s		
90"	374	4418	8.47	0.115	1.875	0.01856			
84"	374	3848	9.72	0.115	1.750	0.02683			
84"	364	3848	9.46	0.115	1.750	0.02549			
90"	364	4418	8.24	0.115	1.875	0.01751			
90"	335	4418	7.58	0.115	1.875	0.01489			

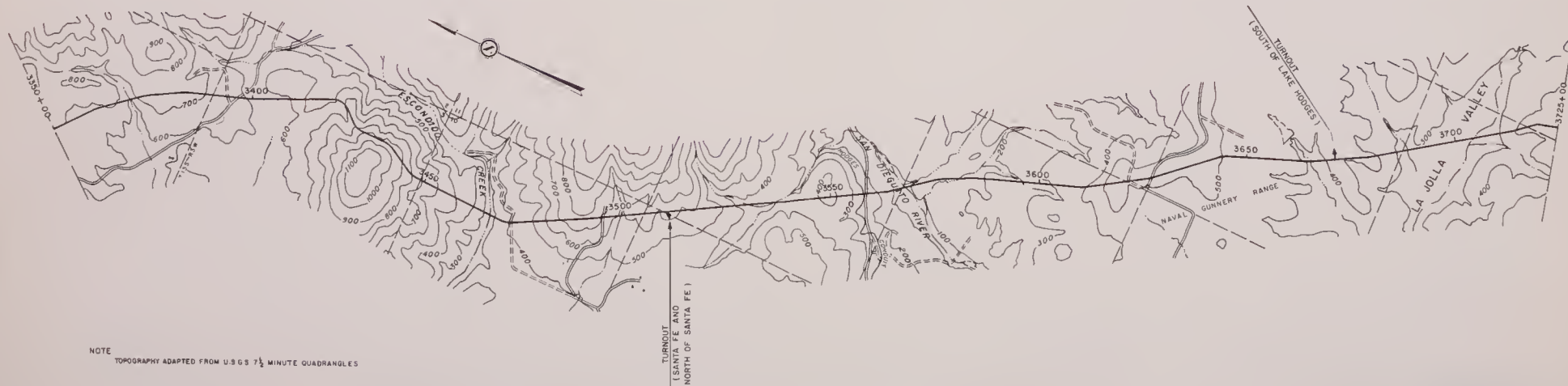
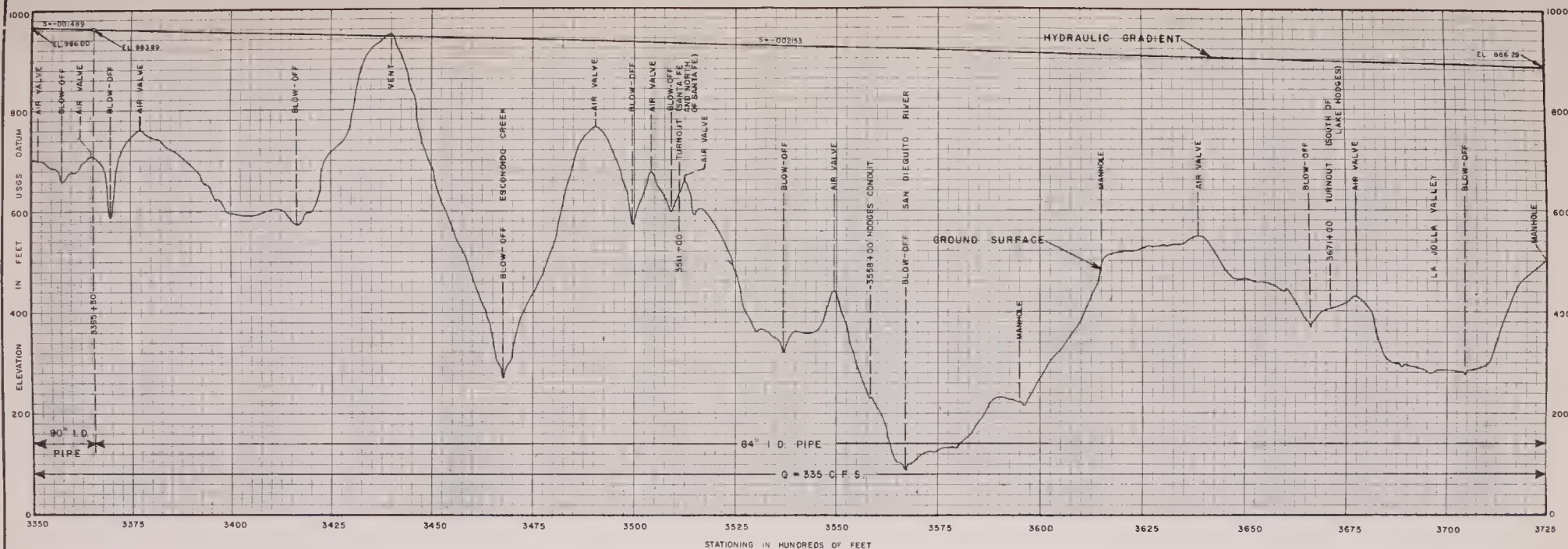
NOTE
TOPOGRAPHY ADAPTED FROM USGS 7 1/2 MINUTE QUADRANGLES

STATE OF CALIFORNIA DEPARTMENT OF WATER RESOURCES SOUTHERN CALIFORNIA DISTRICT			
PROJECT FEATHER RIVER			
FEATURE SAN DIEGO ADEDUCT PLAN AND PROFILE STA 2975+00 TO STA 3350+00			
DESIGNED FEJ	SUBMITTED J. B. Withers	APPROVED Max Robinson	DATE 12/2/57
DRAWN JPS & RPB	RECORDED J. B. Withers	CHECKED J. B. Withers	FILE NO.
REV	DATE	DESCRIPTION	APP





STATE OF CALIFORNIA DEPARTMENT OF WATER RESOURCES SOUTHERN CALIFORNIA DISTRICT			
PROJECT		FEATHER RIVER	
FEATURE		SAN DIEGO AQUEDUCT PLAN AND PROFILE STA. 4850+00 TO STA. 5225+00	
DESIGNED E.F.J.	SUBMITTED K. & W. Webb Presented J. D. Hester	APPROVED DATE 1/26/67 Max Berkman District Engineer	
DRAWN JPB & RPB	RECOMMENDED J. D. Hester Principal Hydraulic Engineer	APPROVAL RECOMMENDED J. D. Hester Principal Hydraulic Engineer	DRAWING NO FILE NO
CHECKED J.R.K.			
DESCRIPTION	SUB	APPD	



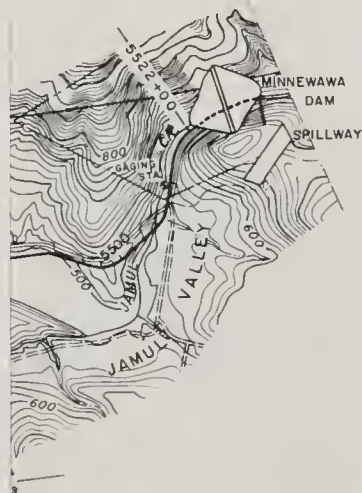
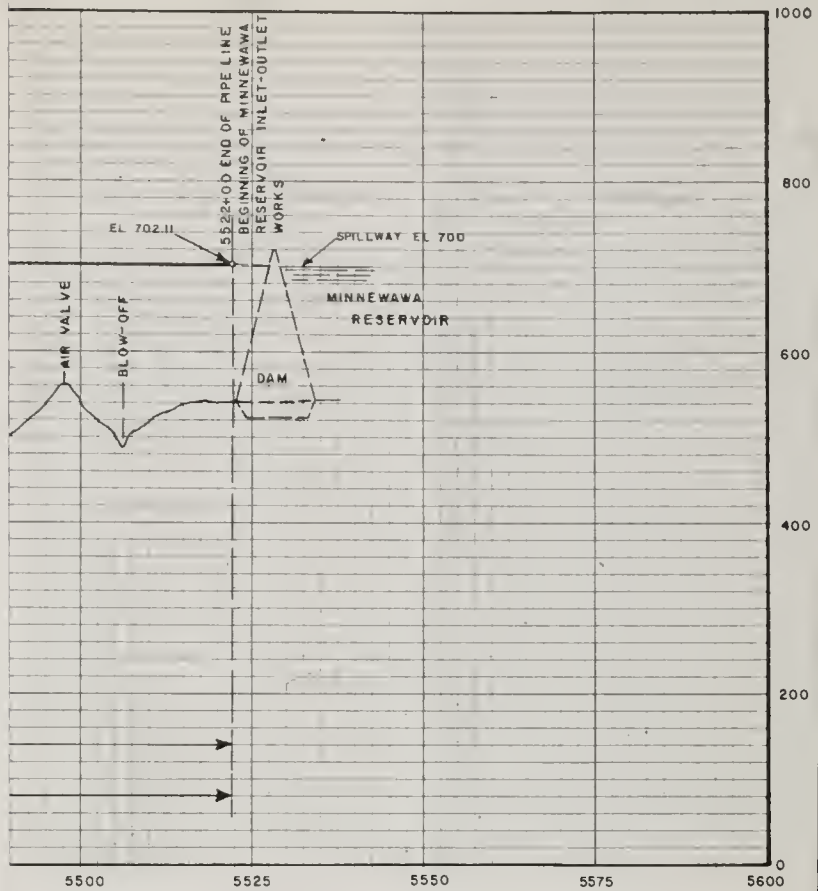
NOTE
TOPOGRAPHY ADAPTED FROM U.S.G.S 7 1/2 MINUTE QUADRANGLES

HYDRAULIC PROPERTIES						
DIA	Q	A	V	n	r	s
90"	335	4418	758	0.15	1875	0.01489
84"	335	3848	871	0.15	1750	0.02153

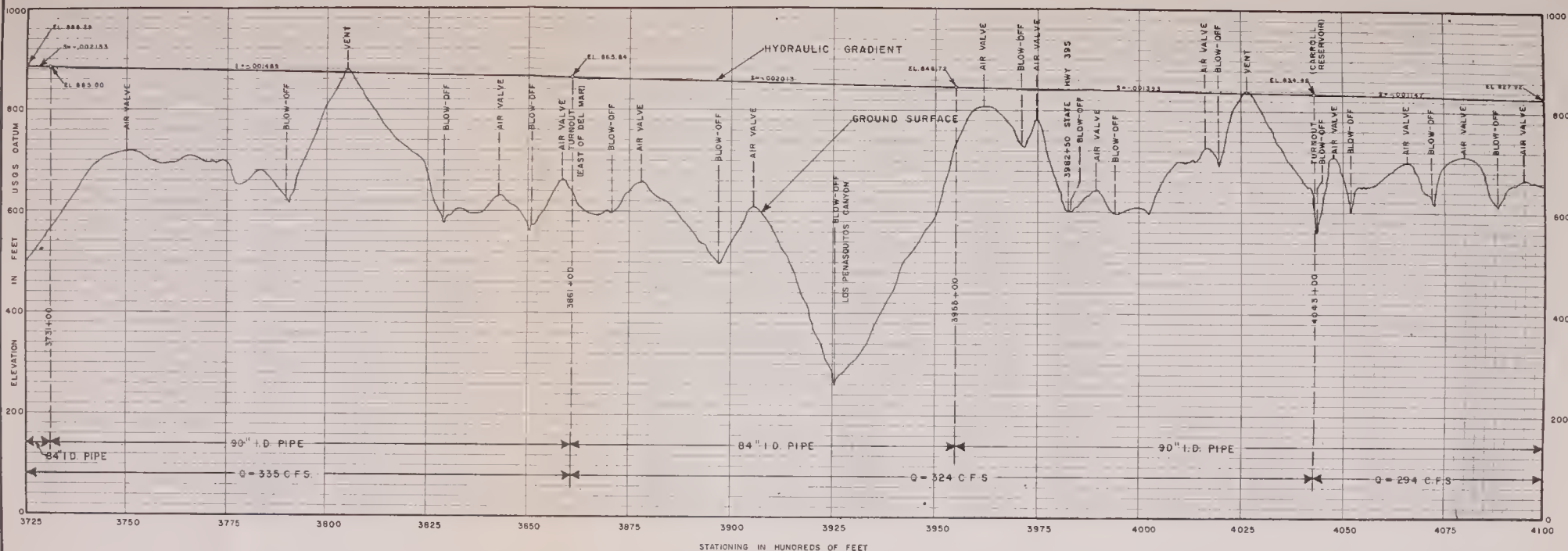
SCALE OF FEET
0 1000 2000

STATE OF CALIFORNIA DEPARTMENT OF WATER RESOURCES SOUTHERN CALIFORNIA DISTRICT	
PROJECT FEATHER RIVER	
FEATURE SAN DIEGO AQUEUCT PLAN AND PROFILE STA. 3350+00 TO STA 3725+00	
DESIGNED E.F.J.	APPROVED DATE 1/1/57
CHECKED R.A.V.	RECOMMENDED DATE 1/1/57
REV	DATE
DESCRIPTION	DATE

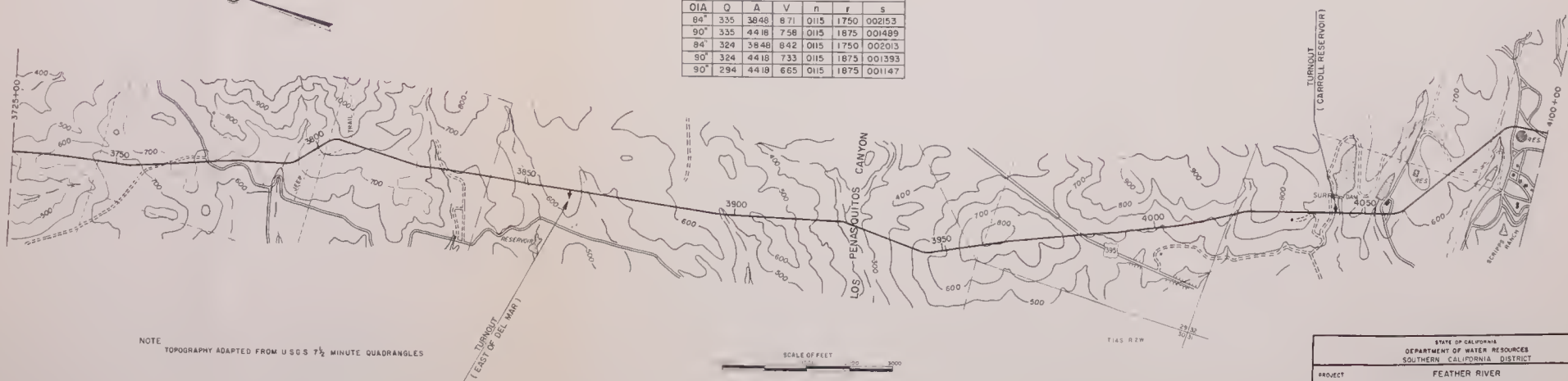




STATE OF CALIFORNIA DEPARTMENT OF WATER RESOURCES SOUTHERN CALIFORNIA DISTRICT			
PROJECT FEATHER RIVER			
FEATURE SAN DIEGO AQUEDUCT PLAN AND PROFILE STA. 5225+00 TO STA. 5522+00			
DESIGNED E. J.	SUBMITTED K. W. [Signature] [Signature]	APPROVED DATE 1/15/53 [Signature]	
DRAWN L. S. G.	RECOMMENDED [Signature]	DISTRICT ENGINEER [Signature]	
CHECKED [Signature]	APPROVAL RECOMMENDED R. W. [Signature]	DRAWING NO.	FILE NO.
DESCRIPTION	SUB	APPD	

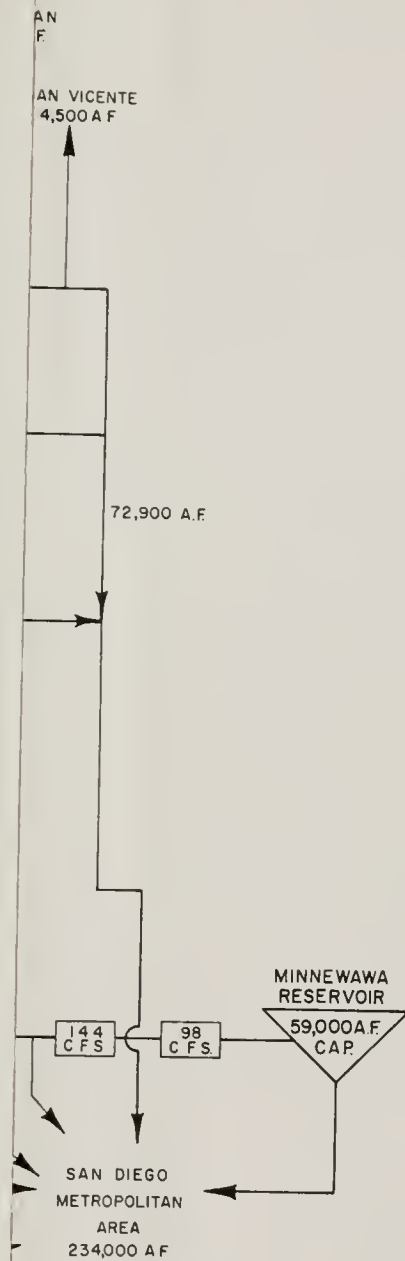


HYDRAULIC PROPERTIES							
OIA	Q	A	V	n	f	s	
84"	335	3848	8.71	0.015	1750	002153	
90"	335	4418	7.58	0.015	1875	001489	
84"	324	3848	8.42	0.015	1750	002013	
90"	324	4418	7.33	0.015	1875	001393	
90"	294	4418	6.65	0.015	1875	001147	

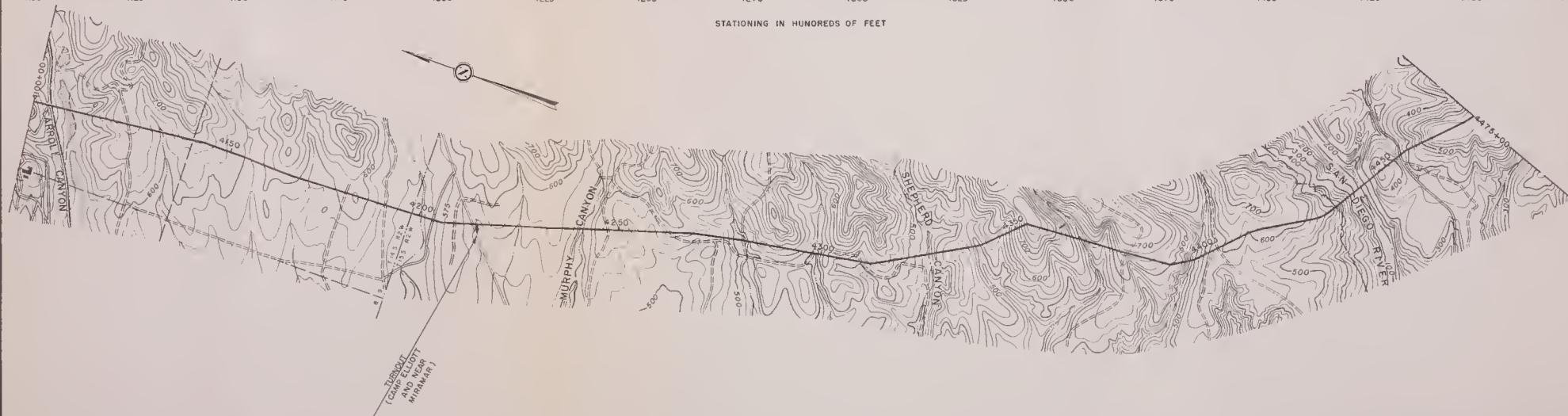


NOTE
TOPOGRAPHY ADAPTED FROM USGS 7 1/2 MINUTE QUADRANGLES

STATE OF CALIFORNIA DEPARTMENT OF WATER RESOURCES SOUTHERN CALIFORNIA DISTRICT			
PROJECT FEATHER RIVER			
FEATURE SAN DIEGO AQUEDUCT PLAN AND PROFILE STA. 3725+00 TO STA. 4100+00			
DESIGNED EEJ	SUBMITTED 10/1/68 JPS & LSG	APPROVED DATE: 12/2/68 Max Gordon	
CHECKED [Signature]	RECOMMENDED [Signature]	FILE NO.	
REV	DATE	DESCRIPTION	FOR APPD



STATE OF CALIFORNIA
 DEPARTMENT OF WATER RESOURCES
 SOUTHERN CALIFORNIA DISTRICT
 FEATHER RIVER PROJECT
 INVESTIGATION OF ALTERNATIVE AQUEDUCT
 ROUTES TO SAN DIEGO COUNTY
 SCHEMATIC DIAGRAM
 OF
 ESTIMATED ANNUAL WATER DELIVERIES
 FROM
 EXISTING SAN DIEGO AQUEDUCT AND
 FROM PROPOSED "W" LINE IN THE YEAR 1980



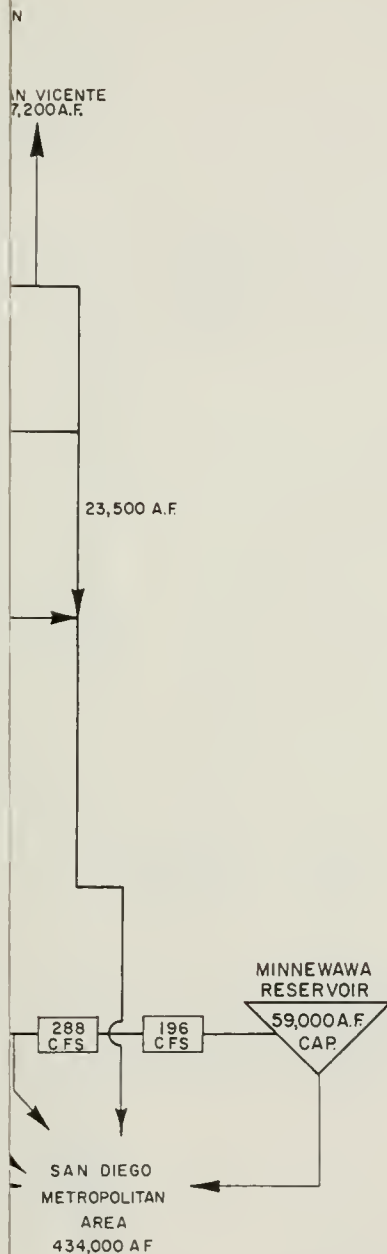
TOPOGRAPHY ADAPTED FROM USGS 7½ MINUTE QUADRANGLES

HYDRAULIC PROPERTIES						
DIA.	Q	A	V	n	r	s
90"	294	44.18	6.65	0.115	1.875	0.01147
84"	286	38.48	7.43	0.115	1.75	0.01569

SCALE OF FEET

STATE OF CALIFORNIA DEPARTMENT OF WATER RESOURCES SOUTHERN CALIFORNIA DISTRICT			
PROJECT			
FEATHER RIVER			
SAN DIEGO AQUEUCT			
PLAN AND PROFILE			
STA. 4100+00 TO STA. 4475+00			
DESIGNED	SUBMITTED	APPROVED	DATE
<i>W. J. W.</i>	<i>8-6-68</i> <i>3/27</i> <i>RECEIVED</i>	<i>Wes. Johnston</i>	
DRAWN	RECORDED		
<i>W. J. W.</i>			
CHECKED	APPROVED FOR RECORD	DRAWING NO.	SHEET NO.
<i>3/26</i>	<i>W. J. W.</i> <i>W. J. W.</i> <i>W. J. W.</i>		



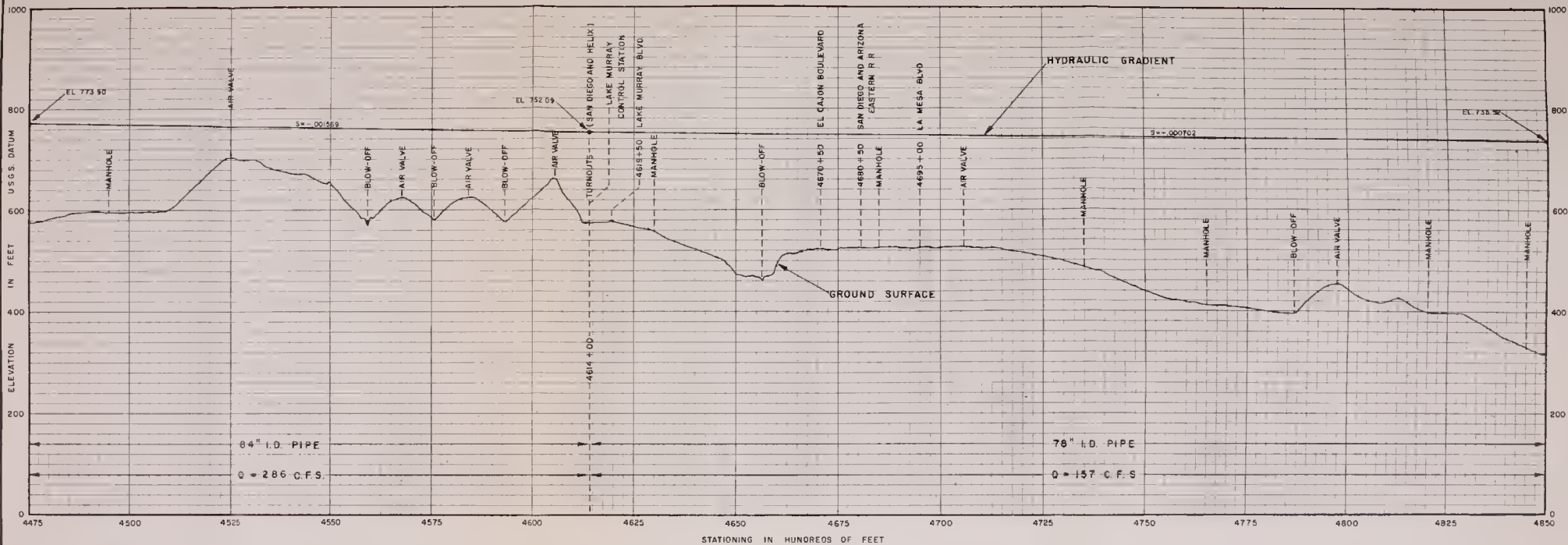


STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT
FEATHER RIVER PROJECT

INVESTIGATION OF ALTERNATIVE AQUEDUCT
ROUTES TO SAN DIEGO COUNTY

SCHEMATIC DIAGRAM
OF
ESTIMATED ANNUAL WATER DELIVERIES
FROM
EXISTING SAN DIEGO AQUEDUCT AND
FROM PROPOSED "W" LINE IN THE YEAR 2000



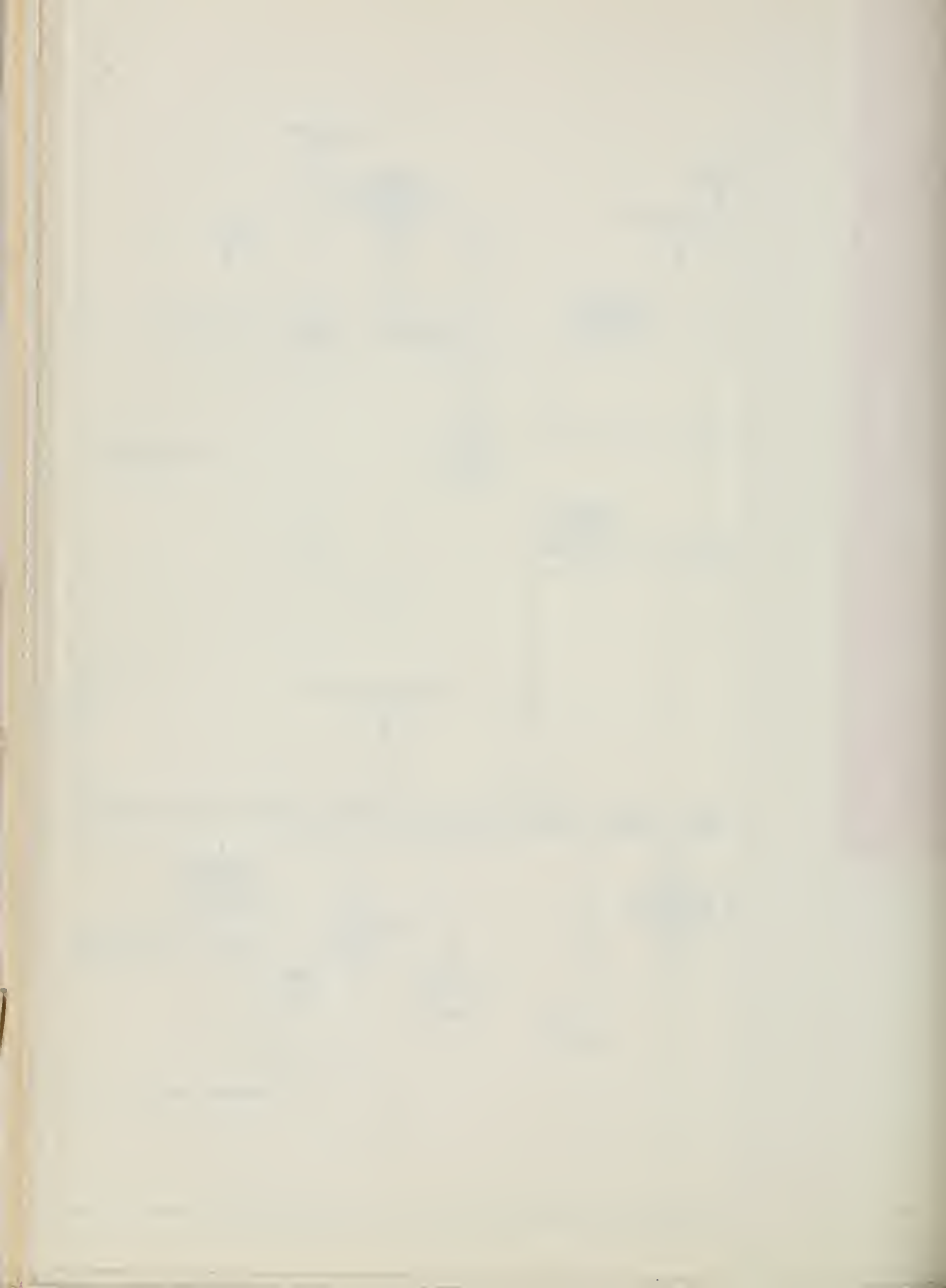


NOTE
TOPOGRAPHY ADAPTED FROM USGS 7 1/2 MINUTE QUADRANGLES
HOUSES SHOWN NEAR AQUEDUCT ALIGNMENT ONLY

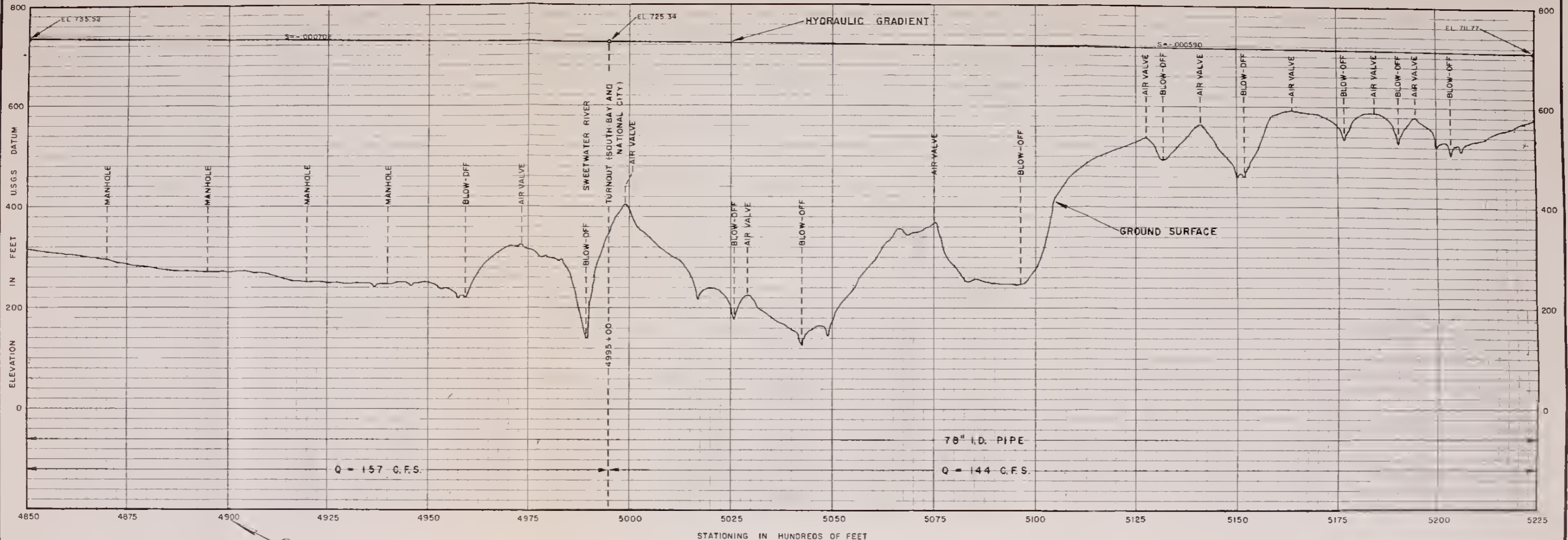
HYDRAULIC PROPERTIES						
DIA	Q	A	V	n	r	s
84"	286	38.48	7.43	0.015	1.75	0.001569
78"	157	33.18	4.73	0.015	1.625	0.001702

SCALE OF FEET
0 100 200 300

STATE OF CALIFORNIA DEPARTMENT OF WATER RESOURCES SOUTHERN CALIFORNIA DISTRICT			
PROJECT FEATHER RIVER			
FEATURE SAN DIEGO AQUEDUCT			
PLAN AND PROFILE STA 4475+00 TO STA 4850+00			
DESIGNED FEU	SUBMITTED 8/8/44	APPROVED DATE 1/12/45	
DRAWN VJB & RPB	RECOMMENDED DATE	Checked Engineer M. J. Johnson	
CHECKED R. M. Johnson	APPROVAL DATE	DRAWING NO.	FILE NO.



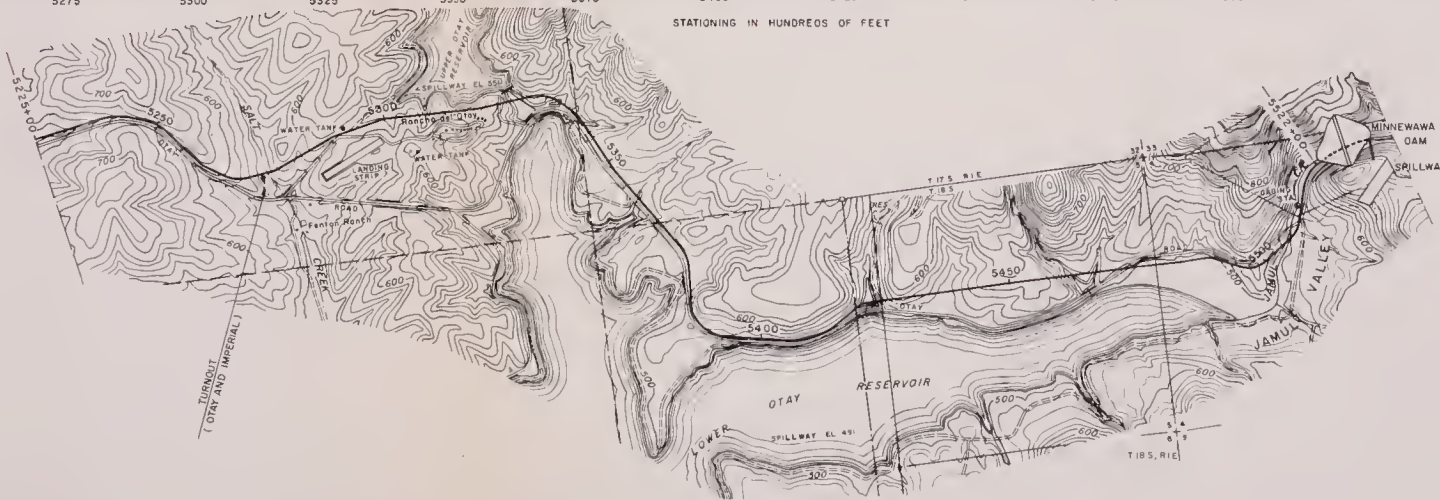
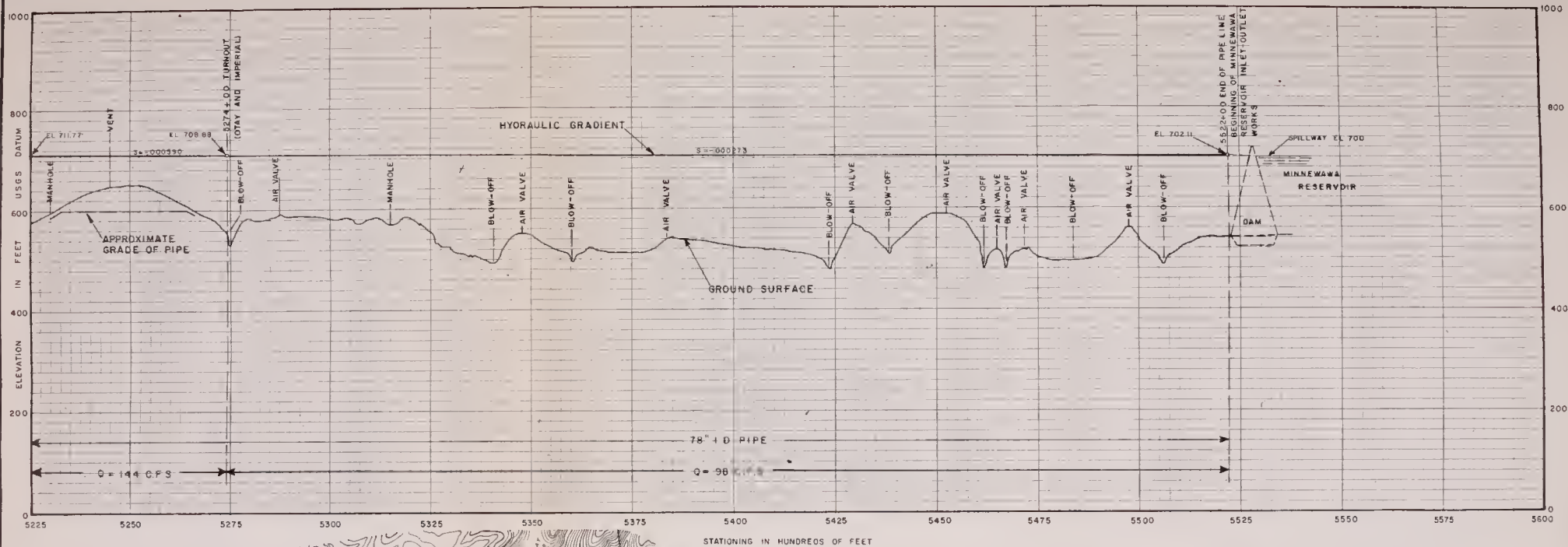
APPENDIX A
CORRESPONDENCE



HYDRAULIC PROPERTIES						
DIA	Q	A	V	n	r	S
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78"	144	3318	4.34	.0115	1.625	.000590



STATE OF CALIFORNIA DEPARTMENT OF WATER RESOURCES SOUTHERN CALIFORNIA DISTRICT	
PROJECT FEATHER RIVER	
FEATURE SAN DIEGO AQUEDUCT PLAN AND PROFILE STA. 4850+00 TO STA. 5225+00	
DESIGNED EEJ	SUBMITTED K. B. Wilkes
DRAWN JPB & RPB	RECOMMENDED P. M. Edmonstone
CHECKED JJK	APPROVED P. M. Edmonstone
DATE 1/24/67	DATE 1/24/67
DRAWING NO.	FILE NO.



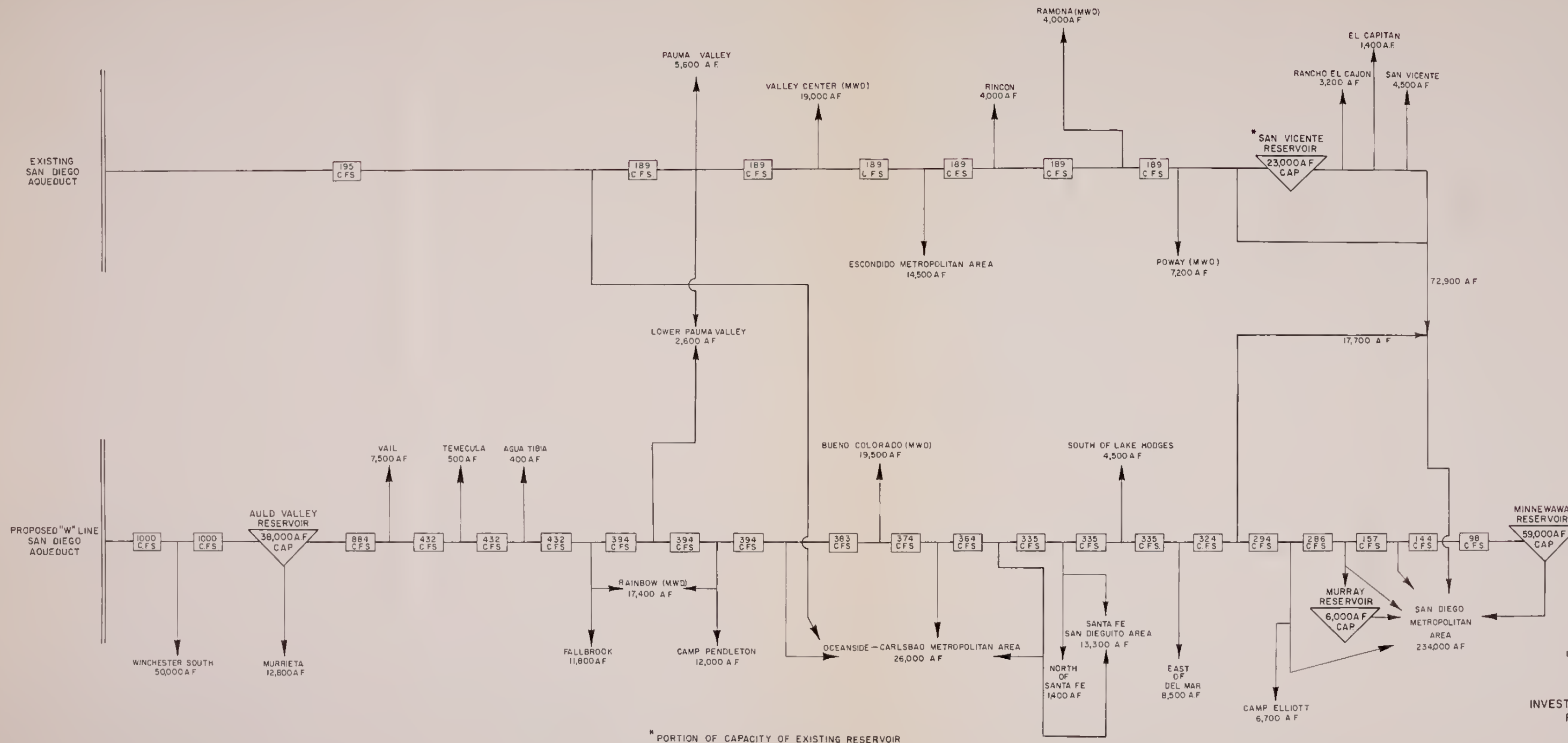
HYDRAULIC PROPERTIES						
O/A	O	A	V	n	r	s
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78"	98	33.18	2.95	0.15	1625	0.00273

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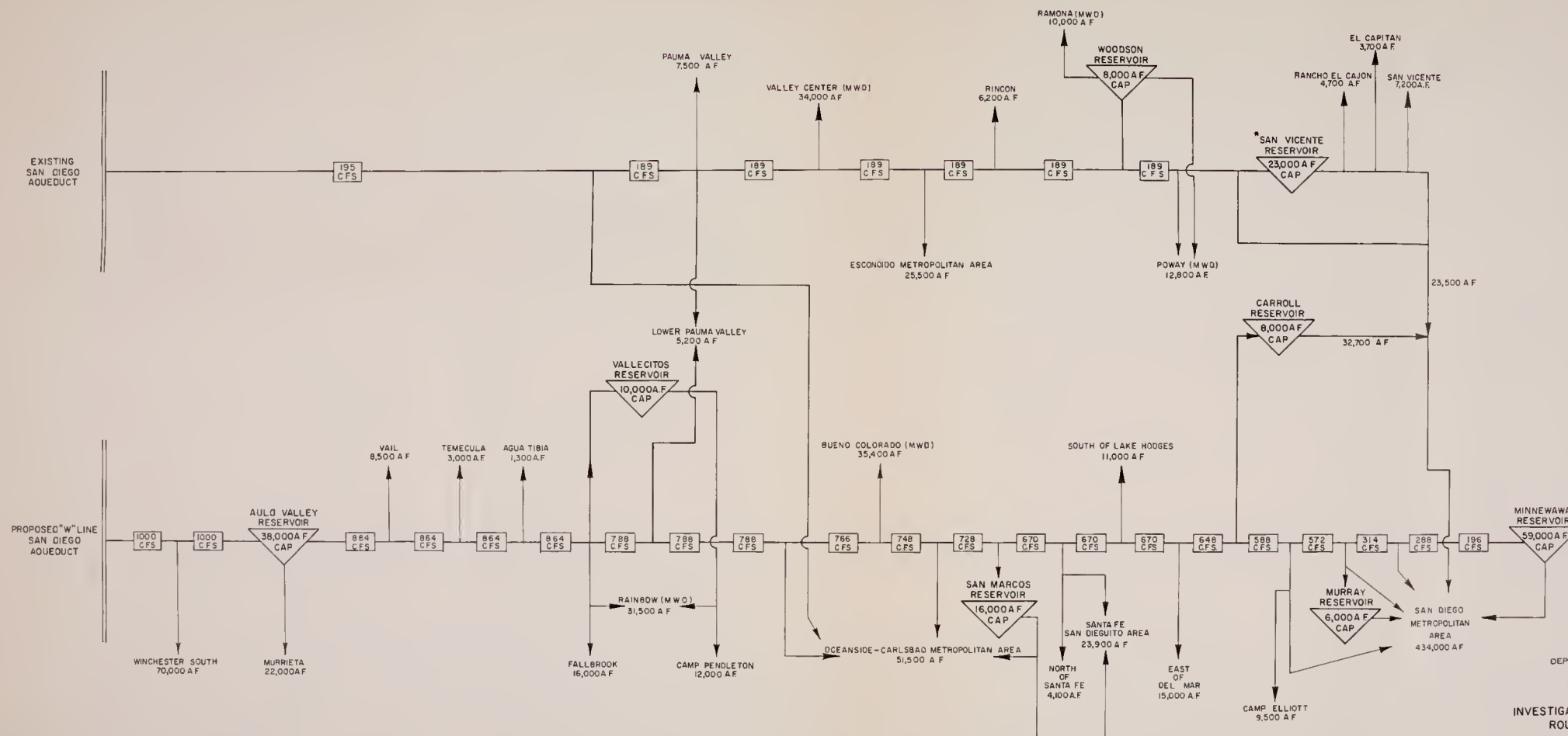
NOTE

TOPOGRAPHY ADAPTED FROM USGS 7 1/2 MINUTE QUADRANGLES

STATE OF CALIFORNIA DEPARTMENT OF WATER RESOURCES SOUTHERN CALIFORNIA DISTRICT	
PROJECT FEATHER RIVER	DATE 1/10/53
FEATURE SAN DIEGO AQUEDUCT PLAN AND PROFILE STA. 5225+00 TO STA. 5522+00	
DESIGNED E.C.J.	APPROVED Mr. [Signature]
DRAWN L.S.G.	RECOMMENDED [Signature]
CHECKED [Signature]	APPROVAL [Signature]
REV	DATE
DESCRIPTION	
NO	DATE



STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT
FEATHER RIVER PROJECT
INVESTIGATION OF ALTERNATIVE AQUEDUCT
ROUTES TO SAN DIEGO COUNTY
SCHEMATIC DIAGRAM
OF
ESTIMATED ANNUAL WATER DELIVERIES
FROM
EXISTING SAN DIEGO AQUEDUCT AND
FROM PROPOSED "W" LINE IN THE YEAR 1980



* PORTION OF CAPACITY OF EXISTING RESERVOIR

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT
FEATHER RIVER PROJECT
INVESTIGATION OF ALTERNATIVE AQUEDUCT
ROUTES TO SAN DIEGO COUNTY
SCHEMATIC DIAGRAM
OF
ESTIMATED ANNUAL WATER DELIVERIES
FROM
EXISTING SAN DIEGO AQUEDUCT AND
FROM PROPOSED "W" LINE IN THE YEAR 2000

January 3, 1957

Board of Directors
Metropolitan Water District
of Southern California
306 West Third Street
Los Angeles, California

Board of Directors
San Diego County Water Authority
2750 Fourth Avenue
San Diego 3, California

Gentlemen:

Pursuant to the provisions of Item 419.5 of the Budget Act of 1956 of the California Legislature, this Department is conducting an investigation of alternative Feather River Project aqueduct routes to San Diego County. Work on this investigation is essentially completed and preparation of a report thereon is now in progress. It is proposed to submit the report to the Legislature on or about February 1, 1957. Time being of the essence, certain conclusions of our investigation were submitted at a meeting of the Engineering Advisory Committee on Feather River Project Aqueduct Route Studies on December 19, 1956, contained in a "Statement by State Department of Water Resources on Investigation of Alternative Feather River Project Aqueduct Routes to San Diego County". A copy of the foregoing statement is attached hereto.

We intend to include in our report to the Legislature recommendations as to the capacity and alignment for an aqueduct to San Diego County which would not only convey Feather River Project water but also, in the interim until such water is available, could carry Colorado River water.

The present legislative authorization of the Feather River Project includes delivery of water via the so-called "High Line" route as far south as Horsethief Canyon in San Diego County. If the State of California is to participate in financing and/or constructing an aqueduct, as described in the enclosed statement, as a unit of the Feather River Project, new legislation would be required reauthorizing the project in accordance with the revised alignment.

We understand that the Metropolitan Water District of Southern California and the San Diego County Water Authority are preparing plans and are considering the financing and construction of the next aqueduct

Boards of Directors
Metropolitan Water District
of Southern California
San Diego County Water Authority

-2-

January 3, 1957

to San Diego County. We also are in receipt of Resolution No. 135542, dated October 2, 1952, of the City Council of San Diego, which expresses the desire for State participation in this project, and reauthorization of the Feather River Project in accordance with the findings of the Department's current investigation.

In order for this Department to make proper recommendations to the Legislature in our afore-mentioned report, we must be fully informed as to the desires and plans of the Metropolitan Water District of Southern California and the San Diego County Water Authority in this regard. It would, therefore, be appreciated if you would advise us, in time for use in our present report, of the intentions of your agencies with respect to financing and construction of the next aqueduct to San Diego County.

Very truly yours,

HARVEY O. BANKS
Director of Water Resources

By /s/ Max Bookman
Max Bookman
District Engineer

Enc.

cc: City Council
City of San Diego
Dept. of Water Resources
Sacramento

January 24, 1957

Mr. Harvey O. Banks
Director of Water Resources
P. O. Box 1079
Sacramento 5, California

Dear Mr. Banks:

Your letter signed by Max Bookman, District Engineer, and addressed jointly to the Board of Directors of this District and of the San Diego County Water Authority under date of January 3, 1957, enquiring as to the respective intentions with regard to the financing and construction of the next aqueduct to serve the member-areas in San Diego County is hereby acknowledged.

Following its consideration on January 22, 1957, the Board of Directors instructed me to inform you that it is the intention of this District to build an aqueduct to deliver additional water to the San Diego County Water Authority and that construction on it will begin within the present year.

Previously, on January 8, 1957, your foregoing letter was referred to Mr. Robert B. Diemer, General Manager and Chief Engineer. His specific recommendations contemplate an aqueduct capable of delivering to San Diego County 180,000 acre feet of water a year, the first 16 miles from the point of diversion at the Colorado River aqueduct to Auld Valley to be open canal having a capacity of 500 cfs and the remainder to be a pipe line having a capacity of 250 cfs.

Very truly yours,

BOARD OF DIRECTORS OF THE
METROPOLITAN WATER DISTRICT
OF SOUTHERN CALIFORNIA

By /s/ Joseph Jensen
Joseph Jensen, Chairman

cc: SDCWA
Mr. Max Bookman

2750 FOURTH AVENUE
SAN DIEGO 3, CALIFORNIA

January 29, 1957

Mr. Max Bookman
District Engineer
State Department of Water Resources
P. O. Box 15718
Los Angeles 15, California

Dear Mr. Bookman:

This letter is in reply to your telephone call of last week in regards to your letter dated January 3, 1956. No action was taken on this letter by the Authority Board at its meeting on January 10, since action of our Board would depend on the action taken by the Metropolitan Water District with respect to construction of the Second Aqueduct.

You have received by now a copy of a letter from the Chairman of the Metropolitan Water District giving results of Metropolitan Water District Board action on January 22, in which the District agreed to build the northern portion of the Aqueduct, with construction to begin within the present year.

The Authority Board, at its meeting on November 9, adopted a statement of policy relative to the construction of the Second San Diego Aqueduct, in which it urged the immediate construction of the Aqueduct by Metropolitan Water District; and support for a bond issue within the Authority area to finance the Authority's section of the Aqueduct. A copy of this statement is enclosed.

It appears that this might be the answer to your letter, now that Metropolitan has definitely decided to go ahead with its portion of the Aqueduct.

Also bearing on this matter, is action taken by the Authority Board at its January 15 meeting, which authorized and directed me to proceed with the preparation of engineering plans and specifications for the Second Aqueduct along the westerly route, as set forth in the State's alternate aqueduct route study, subject to such modifications as may be desirable in the light of further engineering studies.

I hope this will give you the information requested in your letter of January 3.

Very truly yours,

/s/ Richard S. Holmgren
Richard S. Holmgren
General Manager & Chief Engineer

Enclosure

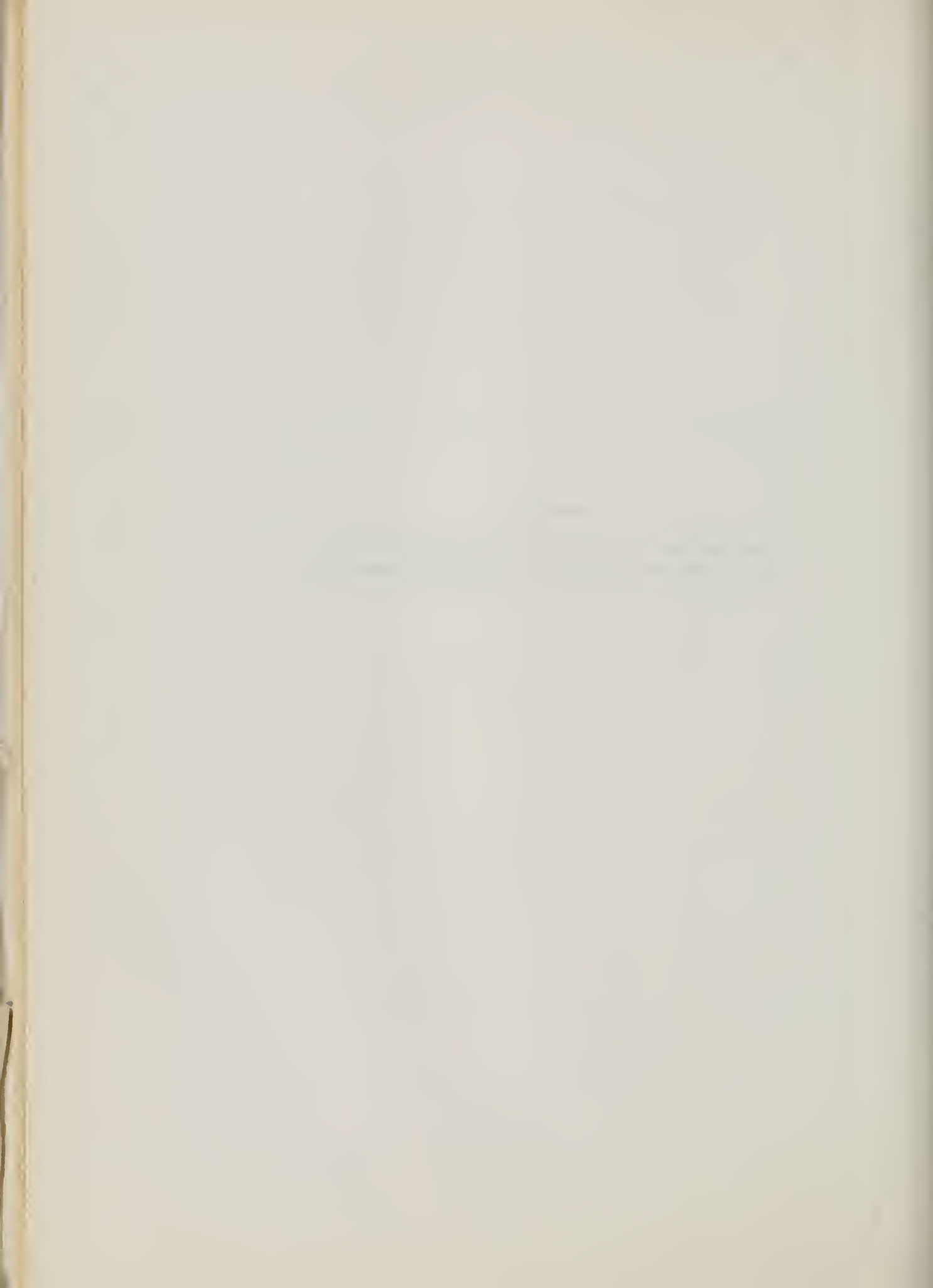
STATEMENT OF POLICY OF THE BOARD OF DIRECTORS
OF THE SAN DIEGO COUNTY WATER AUTHORITY RELA-
TIVE TO THE CONSTRUCTION OF A SECOND SAN DIEGO
AQUEDUCT AND IN SUPPORT OF THE FEATHER RIVER
PROJECT AND CALIFORNIA WATER PLAN.

1. In order that San Diego County's immediate water needs can be supplied at the earliest possible date, responsible officials of all agencies distributing public water supplies are urged to join with the Board of Directors of the San Diego County Water Authority,
 - (a) in securing the immediate construction of an aqueduct by The Metropolitan Water District of Southern California from a connection with its Colorado River Aqueduct to its point of delivery in San Diego County, and
 - (b) in supporting a bond issue within the Water Authority to finance the extension of such an aqueduct southerly through the Authority's service area.
2. In order that additional water supplies shall be made continuously available when the Colorado River supplies are put to full use, such agencies are urged to continue their all-out support of the State's Feather River Project and other features of the California Water Plan.

(Adopted by the Board of Directors of the San Diego County Water Authority at its regular meeting on November 8, 1956.)

APPENDIX B

DESCRIPTION OF FACILITIES OF THE PROPOSED SAN
DIEGO AQUEDUCT SELECTED FOR INITIAL CONSTRUCTION



Description of Facilities of the Proposed San
Diego Aqueduct Selected for Initial Construction

There is presented following a description of the canal, pipe line, and storage facilities recommended for construction as the initial stage of the proposed San Diego Aqueduct. The facilities selected for initial construction include 29.5 miles of canal section with capacity varying from 1,000 to 884 second-feet, and 74.5 miles of pipe line constructed on the "W" line with a capacity varying from 432 second-feet to 98 second-feet, and Auld Valley Reservoir with a gross storage capacity of 38,000 acre-feet. Typical designs of facilities appurtenant to the proposed aqueduct are shown on Plates 11 through 21 and the plans and profiles of the recommended line are shown on Plate 24 in 15 sheets. The layouts and designs shown on the foregoing plates and described in detail following were the basis for a detailed estimate of capital cost for the proposed aqueduct enclosed as Appendix D of this report.

The canal section of the proposed aqueduct was designed with a conveyance capacity of 1,000 second-feet for the reach from the west portal of San Jacinto Tunnel to a point on the north slope of Auld Valley in Section 2, T. 7 S., R. 2 W., S.B.B.&M., a distance of 23 miles.

At this point the canal would discharge into Auld Valley Reservoir, which would be formed by construction of an earthfill dam, approximately 100 feet high and 3,400 feet in length, across the valley at this point. This reservoir would have a gross storage capacity of about 38,000 acre-feet and would provide regulatory storage, made necessary by fluctuating withdrawals of water from the 1,000 second-foot canal to the north, as well as providing regulatory and emergency storage for areas to the south. The reservoir would have an active storage capacity of about 36,000 acre-feet if water surface elevations were fluctuated between the elevation limits of 1,485 feet, the normal water surface in the canal where it enters the reservoir, and 1,424 feet, the minimum water surface in the canal at the end of the reservoir outlet.

The outlet works of the dam would be located on the south side of the valley and would discharge into a canal section designed for a capacity of 884 second-feet. A bypass siphon would also be constructed across the valley immediately downstream from the dam to permit passage of water directly from the 1,000 second-foot canal to the 884 second-foot canal without entering the reservoir. This bypass siphon would have a capacity of 442 second-feet, one half the design capacity of the canal to the south.

From the outlet of Auld Valley Reservoir, the water would continue southerly in a series of canal sections and siphons, a distance of approximately 6.5 miles, to a point on the north rim of Long Canyon, which would be the end of the last canal section. From this point on, the water would be carried to the south in a pipe line laid along the "W" line some 74.5 miles in length, terminating at the Minnewawa reservoir site.

From the end of the canal section to its terminus at the Minnewawa reservoir site, the capacity of the aqueduct would be decreased successively as it passed points of turnout. Capacity at the north end would be 432 second-feet and at the south end, 98 second-feet. The capacity for each reach of pipe line would be one-half of that required to convey the quantities of water estimated to be needed in the service area in the year 2000.

Canal Headworks and Metering Structures

The headworks of the canal section of the proposed aqueduct would consist of a short tunnel intersecting the San Jacinto Tunnel, a flume leading therefrom to a metering structure, and a siphon terminating in the open canal. Following is a description of these works as designed and used for the cost estimate. A preliminary design of these facilities is shown on Plate 13.

Tunnel. Connection to the Colorado River Aqueduct would be made by tunneling from a point about 50 feet east of the west portal of the San Jacinto Tunnel and intersecting that tunnel about 50 feet upstream from the portal. This connection would be made on the southerly side of the existing tunnel. Since it is desirable to bring the water out with a free water surface, a tunnel section of the same cross section as the existing tunnel would be used. During construction of this connection, a partial flow in the existing aqueduct could be maintained by temporarily installing a length of 84-inch diameter steel pipe in the north half of the 16-foot diameter section of the existing tunnel bypassing the construction area. Bulkheads would be constructed across the tunnel at each end of this pipe. This pipe could carry 400 second-feet, the capacity of two of the Colorado River Aqueduct pumping units. It would be necessary to shut down the aqueduct to install and remove the pipe and bulkheads. The pipe, which would be approximately 36 feet long, would be brought into the tunnel in four 9-foot long sections through the top of the existing portal structure but could be removed in one piece through the new tunnel section.

Flume. Immediately downstream from the headwall of the short tunnel section, a 20-foot long transition to an open flume would be constructed. The first 36 feet of this flume section would be a gate section in which would be installed a 13-foot by 15-foot radial gate. This gate would be equipped with motor operated hoist and would be used to regulate the flow into the proposed San Diego Aqueduct.

Since proximity to the existing aqueduct in this area would not permit use of a canal section, the flume would be extended an additional 292 feet to Station 4+00 where it would join a siphon under Soboda Road and the San Jacinto River. The flume section would consist of a 15-inch thick bottom slab,

13 feet wide, and 12-inch thick walls extending to a height of 16 feet above the floor. At the top of the 12-inch walls would be 18-inch by 12-inch longitudinal beams. The 12-inch walls were designed to transmit the earth loads to the floor slab and to the longitudinal beams. The longitudinal beams were designed to take the reaction from the vertical wall and transmit it to 12-inch by 12-inch cross struts located at 25-foot intervals along the flume. An 8-inch cantilever wall would extend vertically above the cross struts to the ground surface. The walls were designed to withstand earth loads of 30 pounds per cubic feet equivalent fluid pressure. The hydrostatic pressure within the flume would be resisted by the backfill of the flume walls which would be compacted to an elevation two feet above the normal water surface and down on 1:1 slopes on each side.

The bottoms of the cross struts would be 15 feet above the floor slab and would provide a freeboard of 2 feet over the maximum water surface. Two-inch diameter standard pipe sections would be installed through the flume walls near the base of the wall and at heights of 5 and 10 feet at approximately 5-foot intervals to act as weep holes. Graded gravel drains would be constructed on the outside of the wall joining the weep holes, and the floor slab would rest on a 12-inch gravel blanket. A 6-inch sewer pipe, longitudinal drain under the center of the floor slab would discharge through a flap valve into the flume section when ground water pressure exceeded hydrostatic pressure within the flume. A six-foot chain link fence would be erected on each flume wall.

Siphon. At Station 4+00, the flume section would be transitioned to a 13-foot inside diameter monolithic concrete pipe siphon which would pass under Soboda Road, through a metering structure and continue under the San Jacinto River terminating with a transition to a canal section at Station 17+50. The siphon would be extended approximately 350 feet beyond the levee on the south

bank of the river to allow passage between the levee and the siphon headwall of any flood flows which might overtop the levee. The embankment around the siphon headwall and the left bank of the canal from the siphon headwall to State Highway 79 would be protected by riprap from possible flood waters. Further study of flood flows to be expected in the San Jacinto River may justify extending the siphon an additional 1,100 feet across State Highway 79.

Metering Station. Between Stations 4+80 and 6+72 of the foregoing siphon, a metering station would be constructed. The water would be measured by a combination of three venturi tubes in parallel. Two of these tubes would be 120 inches by 60 inches and the third tube would be 60 inches by 30 inches. The 120-inch by 60-inch venturi tubes each were designed to measure flows from 125 second-feet to 500 second-feet. The 60-inch by 30-inch venturi tube was designed to measure flows between 125 second-feet and 30 second-feet. Each venturi tube would be equipped with a cone type valve at the throat. These valves were designed to be used only as shutoff valves to enable the operator to select the meter or combination of meters required. The valves would be placed at the throat of the tubes so that they would have minimum sizes. Cone valves of the type which provide a full opening of the same size as the venturi throat, to reduce head losses at the design capacity to a minimum, would be utilized.

In operation, only the 60-inch by 30-inch tube would be used when the quantity of water to be dispatched down the canal would be less than 125 second-feet. When this quantity would be between 125 second-feet and 500 second-feet, a single 120-inch by 60-inch tube would be selected. When the quantity would be in excess of 500 second-feet, both 120-inch tubes would be used. Flows up to 1,125 second-feet could be measured with all three tubes in operation. At the design flow of 1,000 second-feet, the differential pressure for each tube

would be approximately 113 inches of water and a head loss of 11 per cent of this or 1.04 feet was assumed.

The grade line of the siphon was depressed at the meter location to place the top of the tube below the invert of the canal at the downstream end of the siphon. This would insure a full venturi tube at all flows.

The venturi meters would be housed in a vault of reinforced concrete construction. Structural design of the vault is similar to that for the flume section, with the vertical walls of 16-inch thickness transmitting the earth pressure load to the footings and to horizontal beams cast integrally with the walls at a height of 22 feet above the floor. Sixteen-inch square cross struts would take the reactions from the beams and footings, and would be supported by 16-inch square columns at the intersections. A cantilever wall would extend on up to the ground surface and a parapet wall would be provided to prevent entrance of flood waters from the San Jacinto River. An 8-inch thick floor slab would be placed between the wall and column footings and the bottom cross struts. A sump would be placed below the floor level and a sump pump provided.

Canal Section to Auld Valley Reservoir

As stated, the aqueduct would continue, from the headworks and metering structure, in canal section southward to Auld Valley Reservoir, involving siphon crossings of major drainage channels, timber and concrete bridges for road and highway crossings, overhead crossings for minor drainage and irrigation pipe crossings, and turnouts and checks to provide for water deliveries to areas along the alignment.

Canal Grade and Section. At the end of the siphon under the San Jacinto River, the aqueduct would enter an open concrete-lined canal section. Total head loss through the diversion and metering structure was calculated to

be approximately 2.45 feet. Adding 10 per cent to this for safety factor and an additional 0.5 foot to allow for possible future encroachment on the canal freeboard to convey flows greater than the presently considered design capacity results in a total difference of 3.20 feet between the normal water surface elevation of 1504.74 feet at the tunnel portal and the normal water surface of 1501.54 feet at the beginning of the canal section.

Two special conditions in addition to the usual considerations were given consideration in setting the canal grade between its point of beginning and Auld Valley Reservoir. The first and controlling factor was the proposed spillway elevation for the reservoir. To develop the site properly and provide regulatory and emergency storage of 36,000 acre-feet, the spillway elevation was set at approximately 1,485 feet. The foregoing assumption resulted in a difference of 16.54 feet between the normal water surface elevation at the beginning of the canal and the adopted spillway elevation, with a distance along the canal center line of approximately 118,000 feet. A grade of .0001 was adopted for the canal; and, additional head losses through six siphons, computed as previously described under "Preliminary Design Criteria", resulted in a water surface elevation of 1485.85 feet at the point of entrance into Auld Valley Reservoir.

Another special condition affecting the canal grade is the deep rock cut through which the canal must pass between Station 910+00 and Station 945+00. The steeper the canal grade the greater would be the cost of cutting through this hill.

If the plan to build the Auld Valley Reservoir is for any reason abandoned, the design grade of the canal should be re-examined. An evaluation of all factors involved, including the deep cut mentioned above, the size of the canal section at different slopes, the length of the canal at different

slopes and consideration of head loss in decreasing pipe sizes in siphons might result in a somewhat steeper slope.

The base width of the canal cross section was set at 12 feet, which width is considered to be wide enough for efficient use of most excavating equipment. This base width, with a slope of .0001 and 1.5:1 side slopes results in a water depth of 10.49 feet for the 1,000 second-foot canal. One and one-half feet of lining were provided for freeboard to give a lining height of 12 feet. This results in a ratio of water depth to base width consistent with general practice in constructing canals of this size. A relatively high ratio of water depth to base width is desirable since considerable portions of the canal would be located on moderately steep side slopes.

Alignment and Cross Drainage. Based on estimated costs of canal excavation and of compaction of embankments, the most economical depth for the canal section was determined to be one for which the water surface would be approximately one foot above the original ground surface at the canal center line. In general, the canal center line was located to approximate this condition. However, other factors influenced the selection of alignment, such as the buildings and property lines encountered and cross drainage problems. The area traversed by the canal between Station 17+50 and Station 600+00 has very little cross slope and few defined drainage channels except the drainage ditches which parallel most of the roads. Since no drainage would be taken into the canal and the flat cross slope precluded the use of culverts under the canal, the canal would be located with the water surface below the ground level at most of such drainage crossings to permit the use of overchutes without appreciable ponding on the uphill side of the canal, particularly at the road crossings.

Between Station 600+00 and Station 850+00, the canal would be located on fairly smooth ground with moderate cross slopes and quite well defined drainage channels, near the base of steep hills. The canal would be located generally to obtain the most economical depth as described, swinging into the ground at drainage crossings to facilitate construction of overchutes for cross drainage. A siphon would be provided across Domenigoni Valley at Station 773+00 because of the large flood flows from the tributary drainage area.

Between Station 850+00 and the inlet to the Auld Valley Reservoir at Station 1202+00, the canal would be located generally on foothills lying at the base of steep mountainous terrain. Cross slopes would be moderately steep and drainage channels well defined. The topography in this area is too irregular to allow close following of the contour with the canal without using curves of shorter radius than 200 feet, the minimum curvature assumed in this investigation, and without appreciably increasing the canal length. Therefore, in this area, the canal would consist largely of a series of heavy cut sections between which would be sections of heavy fill. In some cases the entire canal prism would be in compacted embankment for short distances. Where drainage from large areas would cross the canal near Station 960+00 and Station 1070+00, siphons would be constructed to carry the canal flows under the drainage channels. Smaller quantities of cross drainage would be taken over the canal with overchutes or under the canal with culverts. Where the drainage channels would be crossed with the canal largely in fill, culverts were used. Where the canal would be largely in cut, drainage crossing overchutes were used. At some overchute locations, the drainage channels on the upstream side of the canal would be filled up with earth to the invert elevation of the overchute inlets to eliminate ponding. Small drainage channels for which overchutes or culverts were not provided would be diverted to adjacent channels by means of drainage ditches constructed at the toe of the uphill canal embankment.

Canal Underdrains. Underdrains for the concrete-lined canal would be provided in areas of high ground water, or where high ground water would result from development of irrigated agriculture. Two sources of information on depths of ground water are available: (1) a series of test holes drilled by the Metropolitan Water District in December, 1956, approximately on the aqueduct alignment, between the San Jacinto tunnel portal and approximately Station 420+00; and (2) logs of the test holes drilled by the U. S. Bureau of Reclamation in 1946, prior to construction of the existing San Diego Aqueduct. These latter holes were drilled along the alignment of the existing San Diego Aqueduct and the logs of the holes, together with other notes on underground conditions experienced in construction of the first barrel of that aqueduct, are shown on the profile drawings in specifications for construction of the second barrel.

The holes drilled by the Metropolitan Water District indicate ground water at depths of approximately 11 to 16 feet in the area between the San Jacinto Tunnel and the San Jacinto Reservoir. Although this would be considerably below the bottom grade of the canal, it is probable that the ground water will rise considerably in this area with increased irrigation and during years of heavy precipitation. Therefore, underdrains would be provided from the beginning of the canal section at Station 17+50 to Station 170+00.

None of the test holes indicate the danger of high ground water in the upper end of the San Jacinto Valley which would be traversed by the canal between Station 170+00 and Station 600+00. Test holes in this area to depths of approximately 25 feet encountered no water.

In the Domenigoni Valley, ground water was encountered at a depth of approximately 10 feet along the alignment of the existing aqueduct. The proposed canal would cross this valley approximately 7,000 feet upstream from the

existing alignment, and it was assumed that high ground water would be encountered there. Therefore, canal underdrains were provided between Station 760+00 and Station 830+00.

The canal underdrains would be constructed by overexcavating the entire canal prism to a depth of four inches and backfilling to the canal subgrade with selected gravel to form a continuous gravel blanket as a foundation for the concrete canal lining. In the bottom of the canal lining, flap valve weeps would be placed in two rows near the bottom of the canal slopes. The flap valve weeps would consist of short lengths of 1-1/2-inch pipe through the canal lining. The upper end of these pipes would be fitted with companion flanges, recessed into the concrete lining one-half inch. A rubber flap would be attached to the flange and would allow water to enter the canal when the pressure under the lining exceeded the pressure due to water depth in the canal.

Turnouts and Checks. Three turnouts would be included in this reach of the canal. They would be designed to supply the requirements of the areas designated as Winchester South and Murrieta. The turnout at Station 416+00 would supply approximately one-third of the needs of the Winchester South area and the turnout at Station 680+00 would supply the remaining two-thirds. The turnout at Station 991+00 would supply approximately one-fourth of the requirements of the Murrieta area. The remaining three-fourths of the requirement for this area would be supplied from the canal reach below Auld Valley Reservoir. The turnouts would consist of concrete pipe leading from the canal through the embankment. A slide gate would be provided at a headwall in the canal bank. The turnouts were designed to discharge the required flow of water from the canal with a six-foot depth of water in the canal. The turnout structures are described in the section of the foregoing report entitled "Preliminary Design Criteria", and a typical design is shown on Plate 19.

In order to ensure a minimum water depth at the turnouts of six feet under all flow conditions, check structures would be located in the canal at planned intervals. The checks are so located that a water depth of six feet would be maintained at any point in the canal between the end of the siphon at Station 162+98 and the reservoir inlet at Station 1202+00 by checking the water to the normal depth of 10.49 feet at the check structures. The checks would be spaced to provide the required water depths at all points rather than at the specified points of turnout since it is probable that additional turnouts at intermediate points may be installed in the future. It is assumed that no turnouts would be required between San Jacinto Tunnel and the siphon under the existing aqueduct at Station 156+10, making a check in this reach unnecessary.

The radial gate which would be installed in the flume section at the inlet to Auld Valley Reservoir near Station 1202+00 would serve as a check. This gate will control the water surface back to Station 956+00 where the next previous check structure would be installed to control the water surface back to Station 553+00. A second check structure at this point would control the water surface for the remaining reach upstream to about Station 156+10. A typical check structure is shown on Plate 17.

Bridges. In this reach the canal would cross two state highways and thirteen county roads. Two methods of road crossing are considered, either carrying the canal under the roadway in a culvert or inverted siphon or carrying the roadway over the canal on a bridge. Because of the desirability of holding head losses in this reach to a minimum, bridges were provided wherever possible. Bridges were provided at all but one road crossing in this reach.

In general the decks of bridges crossing the canal would be above the grades of the roadways crossed and ramps leading to the bridges would be required. As previously mentioned, most roads crossing the first 11 miles of

the canal are paralleled by drainage ditches and the canal center line was swung into the cross slope far enough to permit taking this drainage across the canal in overchutes. This procedure also decreased the height and lengths of approach ramps required.

The county road crossing the canal alignment at Station 83+35 is paralleled by two ditches approximately three feet deep with the flow line being below the normal water surface in the canal. Since it would be impractical to change the location of the canal center line at this point, a siphon under the road and drainage ditches was used at this crossing.

Concrete bridges 40 feet in width were provided at the two state highway crossings. Concrete bridges 26 feet in width were provided at 8 of the county road crossings and timber bridges 26 feet in width at 4 crossings of secondary county roads. Timber bridges 16 feet in width were provided at all crossings of private roads and at intermediate points within properties which would be severed by the canal right of way. A total of 22 timber farm and private road bridges were included in this reach of the canal. The locations of these bridge structures are shown on the plan and profile on Plate 24. Typical designs of the bridge structures are shown on Plates 14 and 15 and are described in the section of the report entitled "Preliminary Design Criteria".

Santa Fe Railroad Crossing. The canal alignment crosses a branch line of the Santa Fe Railroad at Station 508+80. The crossing would be made by constructing a box type siphon under the tracks with a length of 121 feet between headwalls. Traffic during construction would be handled by construction of a short shoofly or by constructing a temporary falsework to support the tracks in their present position during construction. The siphon would have a design similar to the typical siphon design shown on Plate 12 and previously described in the section of the report entitled "Preliminary Design Criteria".

Aqueduct Crossings. The existing San Diego Aqueduct is crossed by the canal alignment at two places. The first crossing would be at Station 160+00 near San Jacinto Reservoir. A box type siphon 600 feet long, similar to the typical design shown on Plate 12 and described previously in the section of the report entitled "Preliminary Design Criteria", would be provided at this location to carry the canal flow under the two existing 73-inch diameter pipes and also under a drainage channel which crosses the canal alignment at this point. The existing pipes would be supported by falsework during construction of the siphon.

At the second crossing near Station 522+50, the two existing 73-inch diameter pipes are at different elevations. The invert of the lower pipe is approximately 22 feet below ground surface and the top of the upper pipe is approximately 9 feet below ground or 2.5 feet above the normal invert grade of the canal at this point. To avoid the cost of a siphon under these pipes and the loss of head which would result, a modified canal section carrying the water over both pipes was provided. Details of this section are shown on Plate 19. The modified canal section would consist of a reach of canal 55 feet long with a normal water depth of 7.05 feet and bottom width of 33.62 feet. This section would have the same slope and nearly the same velocity as would the normal canal section at the design capacity. This section would be connected to the normal canal section up and downstream by transition sections 50 feet long for the inlet and 40 feet long for the outlet. These transitions were proportioned to maintain a near constant velocity and slope of water surface throughout. Although the theoretical loss of head due to the minute velocity changes is negligible, a loss of 0.10 foot was allowed in the design.

The subgrade of the canal lining would be approximately 7 inches above the top of the existing 73-inch concrete pipe. To strengthen the existing pipe against the increased external loading imposed by the canal structure,

a concrete encasement of the existing pipe up to a level 2 feet above the spring line would be provided. Compacted backfill would be placed in the remainder of the space between pipe and canal lining. In order to drain water which would pond in the canal upstream from this raise in the canal subgrade, an 18-inch concrete pipe drain would be installed, beginning at a sump at the upstream end of the inlet transition and leading to a sump at the downstream end of the outlet transition. This drain would pass under the existing 73-inch pipe, and would have a length of about 145 feet.

Irrigation Crossings. The reach of the canal between Station 17+50 and Station 700+00 would traverse an area which is at present partly under irrigation and the canal alignment would intersect many existing irrigation pipe lines and ditches. The scope and purpose of this design does not permit a detailed analysis of each individual problem thus created. Instead a typical irrigation crossing, as shown on Plate 16, consisting of an 18-inch diameter welded steel pipe carried over the canal was assumed at all crossings. Irrigation crossings were provided at 11 locations where open irrigation or drainage ditches cross the canal or where the existence of underground pipe lines were evident. An additional 20 crossings were included in the cost estimate to provide for pipe line crossings not located and for additional drainage crossings and alterations which would be required due to severance of the irrigated fields.

Classification of Materials to be Excavated. A field reconnaissance of the canal alignment was made by geologists to determine the character of materials to be excavated. It was found that the canal prism would be excavated in materials ranging from loose alluvial fill, that could be excavated easily with scrapers, to extremely hard and massive granite, which would require drilling and blasting. In estimating the quantities of common and rock

excavation, materials were categorized generally into four groups. These groups included: unconsolidated and partially consolidated alluvium which could generally be excavated with scrapers; consolidated alluvium and seamy to massive metamorphic rock which could be broken up with a ripper but might require some drilling and blasting; hard granite rock for the entire section, which would require drilling and blasting; and hard granite rock for part of the section with softer material overlying. The unit prices assumed for excavation in these four classes of materials are included in Appendix C.

From the beginning of the canal to approximately Station 610+00, the canal prism would be excavated entirely in alluvial material consisting of moderately consolidated silts and sands except for a possible localized high point in bedrock in the vicinity of Station 350+00.

From Station 610+00 to Station 670+00, the canal prism would be excavated largely in alluvium with possibly some metamorphic bedrock in the lower portion.

From Station 670+00 to Station 720+00, it is estimated that the lower 80 per cent of the canal prism would lie in hard granite having very few joints and fractures. The remaining 20 per cent of the excavation would be easy going in the overlying alluvium.

From Station 720+00 to Station 850+00, the canal prism would be excavated in the alluvial deposits of Domenigoni Valley with possible localized granitic bedrock highs extending into the bottom of the canal near the edges of the valley.

From Station 850+00 to Station 950+00, the excavation for the canal would be almost entirely in hard granite having little jointing or fracturing. Center line cuts up to approximately 45 feet would be encountered in this portion of the canal and drilling and blasting would be necessary.

From Station 950+00 to Station 975+00, the canal prism would lie in the alluvium of French Valley.

From Station 975+00 to Station 1065+00, the canal prism would lie largely in metamorphic rock. This rock is hard, moderately to strongly fractured and parts well along bedding planes. Alluvium overburden would vary from 10 to 50 per cent of the excavation along this reach.

From Station 1065+00 to Station 1095+00, the canal prism would lie approximately 60 per cent in hard granite and 40 per cent in alluvium.

From Station 1095+00 to Station 1135+00, it is estimated that the lower 80 per cent of the canal prism would be excavated in metamorphic rock with alluvium overburden comprising the other 20 per cent.

From Station 1135+00 to the inlet to Auld Valley Reservoir at Station 1202+00, the excavation will be practically all in hard, moderately to strongly fractured metamorphic rock.

Where the canal prism would be excavated in granite or metamorphic rock, special preparation of the subgrade would be required. It was assumed that the rock would be overexcavated to a minimum depth of three inches below the subgrade of the lining. The space between the lining and the rock excavation line would be filled with a cushion of selected material or crusher run base. In estimating the quantities of foundation preparation for concrete lining, it was assumed that wherever appreciable rock was indicated in the section, the entire section would require this type of preparation.

Inlet to Auld Valley Reservoir. At Station 1202+00, the canal would enter a transition to a flume section. This rectangular flume section would have a width of 20 feet and a normal water depth of 10.49 feet. The flume would curve to the left and parallel the spillway of Auld Valley Dam for a distance of approximately 300 feet with a common center wall. Opposite the ogee

section of the spillway, the elevation of the top of the flume walls would be 1,500 feet, the elevation of the crest of the dam. At this point, a 20-foot wide by 25-foot high radial gate would be installed. This gate would be designed to resist hydrostatic pressure from either side. The gate would be used to control the water surface elevation upstream in the canal, as previously discussed, during normal operation. In the event of heavy natural inflow to Auld Valley Reservoir causing the water surface therein to rise above the spillway lip elevation and the normal water surface elevation of the canal, which would be essentially identical, the gate would be closed to prevent back-flow of flood water into the canal. The gate would be operated automatically. The common wall between the flume section and the spillway would have an elevation 6 inches above the normal water surface in the flume instead of 18 inches of freeboard between normal water surface and top of lining which is maintained throughout the canal. This wall would then act as an overflow wasteway for the canal flow when the radial gate is closed. The length of this lowered section of the wall is sufficient to allow a discharge of 1,000 second-feet without causing overtopping of the canal lining upstream.

The flume would be extended 600 feet beyond the spillway lip into the reservoir area where a drop structure would deliver the water into an unlined channel running down the hillside into the reservoir. At high reservoir stage, the channel and flume in the reservoir area beyond the radial gate section would be inundated. A layout of the flume section and of the dam and spillway at Auld Valley are shown on Plate 21.

Auld Valley Dam and Reservoir

Auld Valley Dam and Reservoir, with a gross storage capacity of 38,000 acre-feet, would be operated to regulate flow from the 1,000 second-foot canal section leading thereto and in the section of the aqueduct south of the

reservoir above Rainbow Pass. These flows would fluctuate throughout the year because of withdrawals of irrigation water from the aqueduct on a peaking basis. The reservoir would also provide emergency storage in case of shutdowns on the Colorado River Aqueduct or on the 1,000 second-foot canal section. A detailed description of the dam and reservoir is included in Appendix E, and a layout of the facilities is shown on Plate 21.

Water would be withdrawn from the reservoir through a vertical outlet tower located near the south abutment. This tower would permit selection of the level from which the water is to be withdrawn. The water would be led under the south abutment of the dam in a 102-inch diameter outlet pipe. At the downstream end of this pipe, the flow would be controlled by two 72-inch, hollow jet valves and measured by two venturi meters. The hollow jet valves would discharge into a stilling basin from which the second section of canal of the proposed San Diego Aqueduct would continue.

Reservoir Bypass Siphon. In order to make it possible to conduct water from the 1,000 second-foot canal section north of Auld Valley directly into the section of canal south of Auld Valley, a bypass siphon would be constructed across Auld Valley. The siphon would consist of 66-inch, inside diameter, concrete pipe, 4,350 feet in length, and would have a conveyance capacity of 442 second-feet. The siphon would take off from a point near the beginning of the flume leading into Auld Valley Reservoir, cross Auld Valley immediately downstream from the dam and discharge into the stilling basin at the end of the outlet works previously described. The pipe would pass under the paved section of the reservoir spillway to minimize the danger of the pipe being washed out by spillway discharge. Flow through the bypass siphon would be controlled by a slide gate at the inlet end. At the outlet end, stop plank guides would be provided so that the siphon could be dewatered with the canal

in operation. A blowoff would be included at the low point in the siphon and a standpipe vent 14 inches in diameter would be provided immediately downstream from the inlet gate. It will be noted that the aqueduct stationing was continued along the bypass siphon on Plate 24.

Canal Section from Auld Valley Reservoir to Beginning of Pipe Line

The canal section of the proposed San Diego Aqueduct would continue from Auld Valley Reservoir outlet works southward from Station 1245+50 to Station 1586+75 where the pipe section would begin. The canal in this reach would have a conveyance capacity of 884 second-feet.

Canal Grade and Section. Selection of the grade and section of the canal leading southward from the Auld Valley Reservoir outlet works was greatly influenced by two considerations: the desirability of minimizing the dead storage in the reservoir, and the topography of the area through which the canal would pass. A normal water surface elevation of about 1,427 feet at the point where the canal section would leave the stilling basin was selected. Under minimum flow conditions in the canal, the check at Station 1441+10, hereinafter described, would maintain a minimum water surface elevation in the canal at the foregoing point of departure from the stilling basin of about 1,424 feet. As indicated in Table E-1 of Appendix E, storage in Auld Valley Reservoir below this latter elevation would be about 2,000 acre-feet. Since the gross storage capacity of the reservoir indicated by the table would be about 38,000 acre-feet, the active storage in the reservoir would be about 36,000 acre-feet.

The alignment and gradient from the foregoing assumed point of beginning were fitted to the topography encountered. The canal was generally directed toward Rainbow Pass through which, as previously discussed, the aqueduct should pass. A study of the maps and field reconnaissance dictated

termination of the canal in the vicinity of Station 1586+75, because the ground elevations beyond this point in the direction of Rainbow Pass fall away rapidly and remain relatively low all the way to the approach to Rainbow Pass. The ground line shown on the foregoing plate demonstrates this condition clearly.

From the point selected as the end of the canal section northward to about Station 1450+00, topography along the general route consists of a series of flat topped ridges having approximate elevations of about 1,420 feet. An attempt was made to bring the canal grade line into the area at about this elevation. By a series of trial and error computations, beginning at the point previously selected as the end of the canal with various starting elevations, the approximate hydraulic grade line of the canal section, including allowance for head losses in intervening siphons, was projected upstream to Auld Valley Reservoir outlet works. It was found that, by starting with a hydraulic grade line elevation of 1,410 feet at the foregoing beginning point, the grade line elevation at the stilling basin at Station 1245+50 would be 1426.8 feet. This latter elevation compared favorably with the elevation of 1,427 feet originally assumed at the Auld Valley Reservoir outlet works as previously discussed. This combination of initial and terminal grade line elevations and gradient was therefore adopted. It will be noted on Sheets 4 and 5 of Plate 24 that the adopted grade line fits the topography quite satisfactorily.

Further refinement of this canal grade and alignment was not considered to be warranted without detailed topography along the proposed alignment. It is possible that some adjustment in the canal grade, section, and siphon sizes will be required when such data are available.

It appears, from preliminary studies made during this investigation, that even if the Auld Valley Reservoir were not to be constructed as part of the aqueduct, the section of canal just described should be constructed to

approximately the grade and alignment shown with a siphon across the Auld Valley approximately between Station 1150+00 and Station 1310+00.

Alignment and Cross Drainage. The reach of the canal between the Auld Valley Reservoir outlet works at Station 1245+50 and approximately Station 1430+00 would be located on rolling hills with moderately steep cross slopes and well defined drainage channels. The ground is too irregular to allow close following of the contour and the canal in this section would be largely a series of alternate cuts and fills. A concrete box siphon would be provided to carry the canal under the unnamed stream which crosses the canal line at about Station 1394+00. All other cross drainage would be taken over the canal in overchutes or under the canal in culverts, which structures have been previously described.

From Station 1430+00 to Station 1586+75, the aqueduct would consist of short sections of canal running along flat topped ridges and connected by siphons crossing the ravines which separate these ridges. Since the canal would be located on or near the tops of these ridges, cross drainage is quite small in quantity of flow in this reach. A few small culverts and overchutes would be provided to carry the small quantities of drainage water which would collect between the ridge tops and the canal embankments.

Turnouts and Checks. Two turnouts were provided in this part of the aqueduct. The turnout at Station 1326+00 would supply approximately three-fourths of the requirements of the Murrieta area and the turnout at Station 1580+00 would supply the requirements of the Vail area.

In order to control the water surface elevation in the canal, checks would be provided. The check at Station 1441+10 would make it possible to maintain a minimum depth of water of 7.5 feet in the canal at Auld Valley Reservoir outlet structure. The check at Station 1517+42 would maintain a minimum

water depth of 6 feet at the end of the siphon at Station 1451+13. This check was included even though no turnouts are presently planned in the affected reach. The two foregoing check structures would be incorporated into the inlet transitions of the siphons as described later for the canal terminal structure and shown on Plate 18. The check at the canal terminal structure, described in an ensuing section, would maintain a minimum water depth of 9.5 feet in the short reach upstream from the canal terminus to the downstream end of the Long Valley Siphon at Station 1547+40.

Bridges and Siphons. This section of canal would be crossed by Buck Road, an unimproved county road, at three places and timber county highway bridges with 26-foot roadway widths would be constructed at each crossing. Crossings of the canal would be provided at the headwalls of each of four siphons included in this reach and therefore no farm bridges were provided. The typical siphon designs previously described were utilized for the four siphon installations.

Canal Terminal Structure. The canal terminal structure is shown on Plate 18. This structure would consist essentially of a transition from the trapezoidal canal section to two 90-inch diameter concrete pipes. One of these pipes would connect to the pipe line which would continue southward and the other would be bulkheaded until the second pipe line stage of the aqueduct is constructed. A check structure would be constructed at the inlet of the transition end and a steel trash rack would be provided at the point of entrance into the 90-inch pipes to prevent entrance of larger sized foreign material into the pipe line. The trash rack would consist of 3/8-inch thick steel bars on 2-1/2-inch centers. Stop plank guides would be provided at the entrance to each 90-inch pipe so that one pipe could be dewatered while the

other is in operation. A sand trap, similar to that shown on Plate 19, would be provided immediately upstream from the terminal structure.

The capacity of the canal between the Auld Valley Reservoir outlet and the beginning of the pipe line would be 884 second-feet and the capacity of the initial pipe line stage beyond this point would be 432 second-feet. As stated, provision would be made for construction of another pipe line with equal capacity bringing the aqueduct capacity to a total of 864 second-feet. The 20 second-foot difference between the canal capacity and total pipe line capacity represents the estimated maximum delivery requirement in the year 2000 for the Vail area. It was assumed that the water taken from the canal at the Vail turnout about 600 feet upstream from the canal terminus would be pumped into Vail Lake and would therefore be subject to sudden interruption by power failure. To provide for this condition under ultimate development with both canal and pipe line operating at full capacity, an overflow wasteway was provided in the design of the canal near the terminal structure. This wasteway would be constructed by lowering a 15-foot length of the canal lining approximately 9 inches or one-half of the normal freeboard, to form a side channel spillway. The overflow would be collected in a small channel and led into a ravine away from the canal. The length of the spillway would be long enough to allow a discharge of 20 second-feet with a depth of flow of 6 inches.

Classification of Materials to be Excavated. From the field examination of the materials to be excavated along the canal alignment, as discussed for the reach of canal north of Auld Valley, the following data were obtained.

From the outlet works of Auld Valley Reservoir to approximately Station 1400+00, it is estimated that the lower portion of the canal prism would be excavated in moderately jointed, slightly weathered granite with the upper 30 per cent being in the overlying alluvium.

From Station 1400+00 to Station 1586+75, the canal prism would be excavated in loosely to moderately consolidated residuum and alluvium with possible occasional outcrops of caliche. All of this material could be easily excavated and was classified as common excavation. This material is also considered to be excellent for construction of the compacted embankments.

The water table in this area is well below the subgrade of the canal sections and is expected to remain so. Therefore, no underdrains would be required.

Pipe Line from End of Canal to Minnewawa Reservoir Site

The general alignment of the aqueduct from the end of the canal to Minnewawa reservoir site would follow that of the "W" line. The location of this line and general construction problems involved have been discussed elsewhere in this report.

Hydraulic Design. The pipe line as designed would be a series of nine inverted siphons, the ends of which would be open to the atmosphere at vent structures located at high points along the alignment. The location and elevation of the vent structure at Rainbow Pass, Station 1900+00, was dictated by the elevation of the pass. A controlling grade line elevation of 700 feet, the spillway lip elevation proposed for Minnewawa Reservoir, was adopted for the terminus of the line. Intervening control points were set from a study of a preliminary profile and hydraulic gradient laid out along the general alignment. Control points were set by running the pipe alignment up to high points. An attempt was made to keep the grade of the pipe line at higher elevations to reduce the head thereon.

Pipe sizes in each reach were then selected so that at the design capacities the hydraulic gradient would meet the controlling elevations. The

design capacity was decreased at the turnouts by the estimated minimum monthly amount of water turned out at that point under full operating conditions, except that capacity changes were not made where this quantity would be less than 8 to 10 second-feet. Where two sizes of pipe were used in a siphon, the smaller pipe was placed where the head would be highest.

The first siphon run of the pipe line would begin at the end of the canal and terminate at the vent structure at Station 1900+00. The relative capacities of the ensuing siphon runs could be adjusted somewhat under varying operating conditions resulting from turnout of more or less water to certain areas than presently estimated, by varying the vent heights, but the head at the beginning of this first siphon would definitely be limited by the canal freeboard. Therefore, an additional five-foot head loss was assumed at the beginning of the first siphon run as a safety factor. This is approximately five per cent of the head loss in the siphon at design flow. Because of this, the plan and profile shown on Sheet 5 of Plate 24 shows a hydraulic grade line elevation at the beginning of the pipe of 1,405 feet as compared with the water surface elevation at the canal terminus previously stated to be 1,410 feet.

Pipe Line Alignment and Accessory Structures. The alignment of the pipe downstream from vents was so arranged that the pipe would proceed downhill from the vents on a straight line until the grade of the pipe would be below the pool level at the next following vent. Wherever possible, the alignment of the pipe between vents was so arranged at intervening summits that the pipe would be below the pool level established at the next downstream vent, and air relief and vacuum valves were provided at all such summit points. Where the foregoing procedure was not possible, such as at Station 2159+00, vents were provided by running the vent pipe up the adjacent hillside to the maximum hydraulic gradient elevation.

Blowoffs were provided at all low points in the pipe line. Access to the interior of the pipe would be provided by manholes at each air valve and blowoff structure, and additional manholes would be provided where required to maintain a maximum length between manholes of 2,500 feet. Details of typical vent, air relief, blowoff, and manhole structures were described previously under "Preliminary Design Criteria", and are shown on Plate 20.

Control Facilities in Terminal Siphon Run. As previously discussed, it would not be necessary to construct Minnewawa Reservoir as a part of the initial works of the proposed San Diego Aqueduct. It was further stated that the reach of pipe line from Station 5325+00, near Otay Reservoir, to Station 5522+00, the point of entrance to Minnewawa reservoir site, would also not be necessary of construction as an initial aqueduct feature. Because of certain operational conditions, hereinafter described, which would exist both before and after construction of Minnewawa Reservoir and the final reach of pipe line, certain flow and pressure control facilities would be provided as described in the following paragraphs.

The ninth and last siphon run would begin at the vent at Station 4355+00 and would end at Minnewawa Reservoir at such time as that reservoir were completed. It is expected that the water surface in this reservoir will vary between elevations 700 feet and 615 feet. With uncontrolled flow in this siphon, the hydraulic gradient would rise and fall with the water surface elevation in Minnewawa Reservoir. This would be satisfactory when the water surface is high in Minnewawa Reservoir. However, when the water surface is low in Minnewawa Reservoir, the hydraulic gradient in the aqueduct would drop along the reach from the terminus back to Station 4355+00. This would be undesirable from the standpoint of operation of the turnouts for City of San Diego and Helix Irrigation District at Station 4614+00, and also would cause the

hydraulic grade line elevation to drop below the pipe grade at several intervening summits making additional pipe vents necessary. Therefore, a station equipped with pressure control devices was provided at Station 4614+00 near Lake Murray. The piping and valve arrangement at this station is shown on Plate 20.

The pressure control station would consist of a 48-inch ball or plug type bypass valve in the main line, two 36-inch unloading pressure control valves, each designed to pass one-half of the design flow through the station, and a 24-inch check valve all arranged in parallel. The 36-inch pressure control valves would be set to maintain the upstream pressure at a constant predetermined value. If the pressure rose, the valve would open and pass water to the ensuing reach of pipe line. If the pressure fell off, the valves would close to maintain the upstream pressure at the set value.

The proposed operation of the control station would be as follows:

(1) When the water surface elevation in Minnewawa Reservoir is between the maximum of 700 feet and approximately 685 feet, the bypass valve would be fully open and all other gate valves closed. This would permit delivery of the design flow of water to a full reservoir. (2) When the water surface elevation in Minnewawa Reservoir is below approximately elevation 685 feet, the pressure control valves would be placed in operation by opening the required gate valves and closing the bypass valve. One valve would be used for flows less than 78 second-feet and both valves for flows in excess of 78 second-feet. The valves would be set to maintain the upstream hydraulic gradient a little below the design hydraulic gradient at this point. Design flows in the aqueduct could still be maintained, since the additional head loss through the control valves would be compensated for by the decreased back-pressure on the pipe terminus resulting from low water surface elevation at Minnewawa Reservoir.

Prior to the construction of Minnewawa Reservoir, the foregoing control station would provide a valuable service in regulating pressure at the turnouts for City of San Diego and Helix Irrigation District. Therefore, the control station was included in the facilities selected for initial construction.

The part of the aqueduct below the last vent structure at Station 4355+00 would be operated on a demand basis. With Minnewawa Reservoir in operation, when water flowing past Station 4355+00 would be in excess of the demands below this point, the excess would flow into Minnewawa Reservoir. When the water flowing past Station 4355+00 would be less than the demand, the additional water would automatically be withdrawn from Minnewawa Reservoir by back-flow in the aqueduct.

In normal operation, an amount of water in excess of the requirements of the City of San Diego and Helix Irrigation District would be flowing past Station 4355+00 at all times, the excess being passed down into the lower reach of pipe line through the pressure control valves. However, if an amount less than this requirement should be entering the pipe line, the hydraulic gradient above the valves would drop until it would be below the normal downstream gradient and water would be fed back through the 24-inch check valve at the control station to supply the deficiency upstream from that point.

In order to permit water to be withdrawn from Minnewawa Reservoir at low water surface elevations and fed back through the aqueduct as far upstream as Lake Murray, it would be necessary to place the pipe line in a deep cut from about Station 5232+00 to about Station 5265+00. To insure proper operation of the pipe line under the reverse flow conditions when the hydraulic gradient would approach the elevation of the pipe along this area of deep cut, the high point in the pipe line would be vented to the atmosphere. This vent would extend above the maximum hydraulic gradient, accomplished by running the vent pipe up the adjacent hillside to the desired elevation. The foregoing condition

demonstrates the need for placing the pipe in deep cut at the stated location to provide for future operation with Minnewawa Reservoir.

The design of the pipe line as an open system made possible the use of pipe designed for hydrostatic heads corresponding to the design hydraulic gradient. However, the stretch of pipe line between the vent at Station 4355+00 and the control station would be designed for a hydrostatic head corresponding to the elevation of the vent at Station 4355+00, since this head could be impressed on the pipe when the valves in the Lake Murray control station are closed.

Interconnection with Existing Aqueduct. In order to effect a greater degree of coordinated operation of the existing and proposed aqueducts to San Diego County, it would be desirable in the future to interconnect the two aqueducts in at least one location. The point of interconnection that would require the least expensive works would be in Rainbow Pass at about Station 1940+00, where the two barrels of the existing aqueduct are less than 50 feet west of the alignment of the proposed aqueduct. Interconnection of the two aqueducts at this point would permit water to be transferred from the proposed line to the existing barrels in the event of interruption of flow in the latter line north of the point of interconnection or on the Colorado River Aqueduct. The provision of the storage reservoir at Auld Valley would make this possible. Because more study and the experience of a few years operation are needed before a decision on interconnection facilities can or need be made, the cost of this interconnection was not included in the cost facilities for initial construction presented in Appendix D.

Trench Excavation and Backfill. For this design, it was assumed that the pipe line would be buried throughout its length. To arrive at estimated quantities of trench excavation, a tentative grade line for the bottom of the

pipe was established on the center line profile, maintaining a minimum cover of three feet. The pipe line was then divided into lengths of approximately 2,500 feet each and average trench depth for each such length was determined. These average depths were used to estimate quantities of excavation for each length of pipe line.

The cross section of the trench used for estimating the excavation quantities is shown on Plate 20. The angle of side slope would vary according to the character of the material. Where conditions would be such that backfill could be consolidated by flooding and jetting, a clearance of nine inches between pipe and trench would ordinarily be used. Where conditions are such that backfill must be consolidated by tamping, the foregoing minimum clearance would be 18 inches. Since it is beyond the scope of this design to accurately determine the locations where each type of trench would be used, a trench excavation section using an average clearance of 12 inches was used. In estimating costs of consolidating backfill, it was assumed that 70 per cent would be consolidated by jetting and 30 per cent by tamping based upon experience in the construction of the existing San Diego Aqueduct.

Between approximately Station 5232+00 and Station 5265+00, the pipe would be placed with an invert grade elevation of approximately 600 feet, necessitating a maximum cut of about 50 feet. This excavation would be made by making a cut to elevation 612 feet with a bottom width of 38 feet. The existing county road which parallels the proposed aqueduct alignment in this reach would be relocated through the cut after placement of the pipe line in a 12-foot deep trench in the road subgrade. The additional road width would be available for installation of the second stage of the aqueduct.

In locating the pipe line alignment, an effort was made to avoid steep cross slopes wherever practical. However, at a few locations, the line was located on steep side slopes, particularly in the vicinity of Station

3250+00 and Station 3440+00. At these locations, additional excavation quantities to provide for benching were included in the estimates.

Between Station 4620+00 and Station 4910+00, the pipe line would be located on or near streets in the towns of La Mesa and Spring Valley. Additional cost of trenching was assumed to allow for the construction difficulties which would be encountered in this area.

Classification of Materials to be Excavated. The material which would be excavated for the pipe trench would vary over a wide range from easily excavated topsoil to hard massive granite. A geological reconnaissance of the line was made to determine the amounts of the various types of materials to be excavated. In preparing estimates of excavation quantities, the two general categories "common" and "rock" were utilized for classification purposes. Common classification was given to all unconsolidated or partially consolidated materials which could generally be excavated with trencher, back hoe, drag line, or scrapers. There is presented following a brief summary of the classification of materials along the aqueduct line.

From the end of the canal to about Station 1850+00 south of the Temecula River, trench excavation would be practically all common. From Station 1850+00 to about Station 2432+00 at the north edge of the San Luis Rey River, excavation would be approximately 87 per cent in rock. From Station 2432+00 to about Station 3082+00 at the north edge of the San Marcos Valley, excavation would be approximately 65 per cent in rock. From Station 3082+00 across the valley to about Station 3217+00, excavation would be all common. From Station 3217+00 to about Station 3585+00 near the San Dieguito River, excavation would be almost exclusively in rock. From Station 3585+00 to about Station 5322+00 at Lower Otay Reservoir, the excavation would be predominantly common, with an estimated 19 per cent classified as rock. From Station 5322+00

to the end of the line at Station 5522+00, the excavation would be almost exclusively in rock.

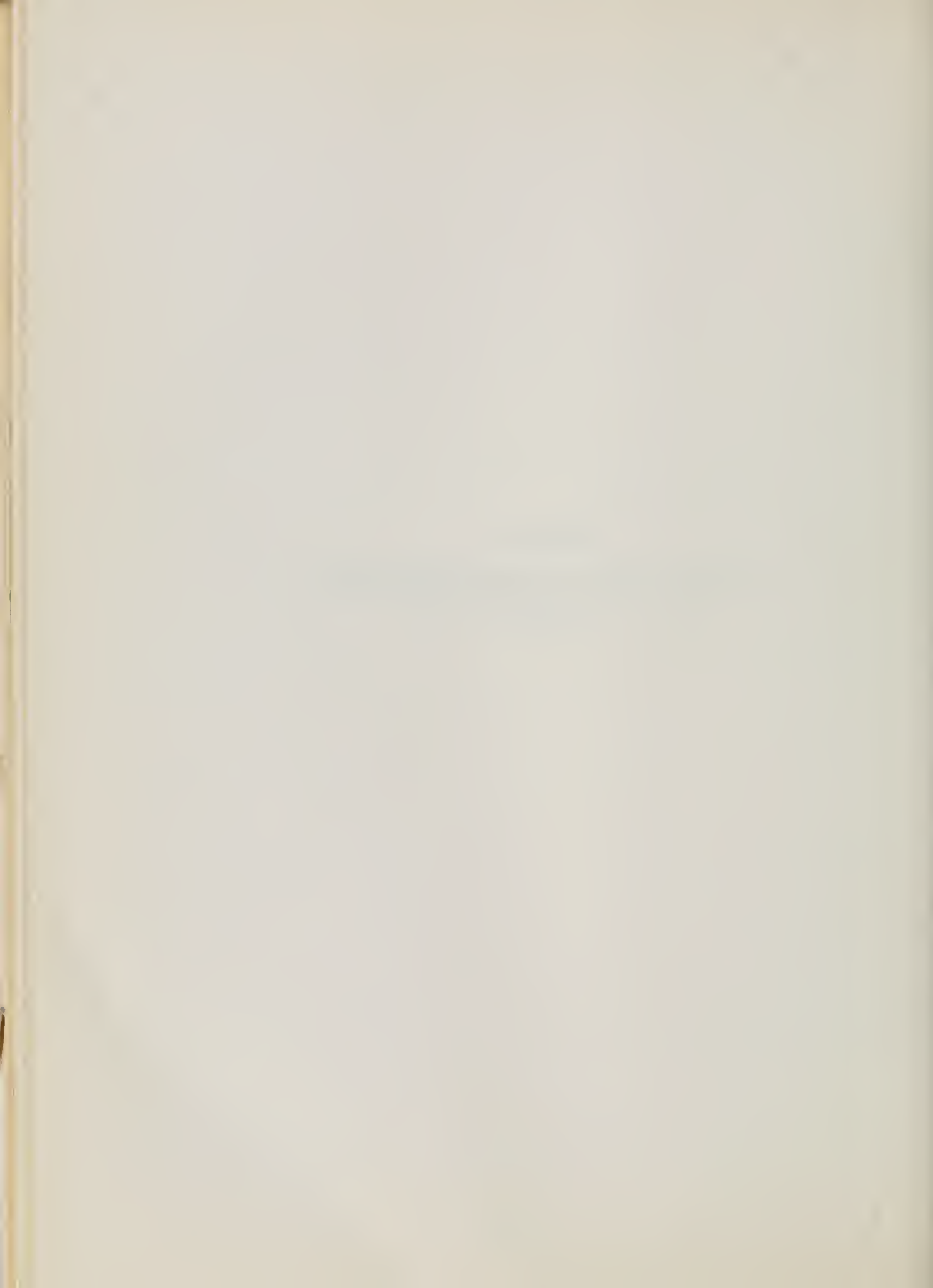
To estimate the cost of excavation, the pipe line was divided into approximately 50 reaches, based on the geological reconnaissance of the line. Estimated trench side slopes and unit prices for excavation were assigned to each reach and the costs were computed using the average trench depths in each 2,500-foot section as previously described above. The unit prices used consisted of base costs for common and rock excavation modified for such special conditions as anticipated high ground water or slumping of trench walls.

Steel and Concrete Pipe. A study of unit prices of furnishing and laying concrete and steel pipe indicated that concrete pipe would be most economical up to heads of approximately 200 feet and steel pipe at heads above 200 feet. In estimating the cost of the pipe, the entire pipe line was divided into nine contiguous sections. These sections were so selected that in each section the head on the pipe would be either nearly all under 200 feet or over 200 feet. For the sections where the head was generally under 200 feet, the use of concrete pipe throughout the section was assumed and estimated prices of concrete pipe for each head class, shown in Appendix C, were used. The unit prices for concrete pipe shown in the estimates in Appendix D are the weighted averages of all head classes and sizes in that section. For the sections where the head was generally over 200 feet, the use of steel pipe was assumed throughout the section and estimated prices of steel pipe for each head class were used. The unit prices of steel pipe shown in the estimates are likewise the weighted average prices for all head classes used within the reach designated.



APPENDIX C

UNIT PRICES USED FOR DETAILED COST ESTIMATES
OF PROPOSED SAN DIEGO AQUEDUCT
"W" LINE



UNIT PRICES USED FOR DETAILED COST ESTIMATES
OF PROPOSED SAN DIEGO AQUEDUCT
"W" LINE

Item	: Unit	: Unit price
<u>Canal Construction</u>		
Excavation for canal, common	cu.yd.	\$ 0.25
Excavation for canal, granitic rock, full section	cu.yd.	2.50
Excavation for canal, granitic rock, partial section	cu.yd.	3.00
Excavation for canal, metamorphic rock	cu.yd.	1.25
Excavation for structures, common	cu.yd.	1.25 to 3.50
Excavation for structures, rock	cu.yd.	4.50
Excavation for drainage channels	cu.yd.	0.40
Compacting canal embankments	cu.yd.	0.45
Compacting road embankments	cu.yd.	1.00
Backfill	cu.yd.	0.70 to 1.50
Compacting backfill	cu.yd.	3.50
Trimming earth foundations for concrete lining	sq.yd.	0.50
Preparing rock foundations for concrete lining	sq.yd.	1.70
4-inch gravel blanket for canal underdrains	sq.yd.	1.25
Furnish and install flap valve weeps	each	7.50
Concrete in canal lining	cu.yd.	23.50
Concrete in structures	cu.yd.	75.00 to 85.00
Furnishing and placing reinforcing steel	lb.	0.16
Furnishing and laying concrete pressure pipe:		
18-inch, head class 50	lin.ft.	6.00
24-inch, head class 50	lin.ft.	6.75
30-inch, head class 50	lin.ft.	10.00
36-inch, head class 50	lin.ft.	13.50
42-inch, head class 50	lin.ft.	15.00
48-inch, head class 50	lin.ft.	18.00
Furnishing and laying corrugated metal pipe:		
18-inch, 12 gauge	lin.ft.	7.50
24-inch, 12 gauge	lin.ft.	9.50
30-inch, 12 gauge	lin.ft.	11.50
36-inch, 12 gauge	lin.ft.	15.60
Furnishing and installing welded steel pipe:		
18-inch, 10 gauge	lin.ft.	11.00
24-inch, 10 gauge	lin.ft.	16.00
30-inch, 10 gauge	lin.ft.	21.05
36-inch, 10 gauge	lin.ft.	27.30
Furnishing and installing couplings and stiffeners	lb.	0.65
Furnishing and installing cast iron slide gates:		
24-inch diameter	each	240.00
36-inch diameter	each	400.00
42-inch diameter	each	470.00
48-inch diameter	each	634.00

UNIT PRICES USED FOR DETAILED COST ESTIMATES
OF PROPOSED SAN DIEGO AQUEDUCT
"W" LINE
(continued)

Item	: Unit	: Unit price
<u>Canal Construction (continued)</u>		
Furnishing and installing radial gates and hoists:		
16-feet by 11-feet	each	\$ 13,200
13-feet by 14-feet	each	12,680
12-feet by 10-feet	each	9,000
Furnish and erect untreated timber in structures	M.B.M.	341.00
Furnish and erect treated timber in structures	M.B.M.	405.00
Furnish and install steel guard railing for bridges	lin.ft.	8.00
Furnish and place gravel on operating road	cu.yd.	4.00
Furnish and place bituminous surfacing for roads	sq.yd.	3.00
Furnish and erect barbed wire right of way fences	mile	2,500
Furnish and erect 6-foot chain link fence	lin.ft.	1.75
Furnish and install metal fence gates	each	50.00
Riprap	cu.yd.	9.00
Gravel blankets and drains	cu.yd.	7.00
Furnish and lay 6-inch pipe drains	lin.ft.	2.00
<u>Pipe Line Construction</u>		
Excavation, common	cu.yd.	0.40 to 3.50
Excavation, rock	cu.yd.	1.50 to 4.50
Backfill	cu.yd.	0.65
Compacting backfill by tamping	cu.yd.	3.90
Consolidating backfill by saturation and vibration	cu.yd.	2.00
Concrete in structures	cu.yd.	93.00
Furnish and place reinforcing steel	lb.	0.18
Furnish and erect 84-inch concrete culvert pipe for shafts of structures	lin.ft.	70.00
Furnish and erect 48-inch concrete culvert pipe for shafts of structures	lin.ft.	50.00
Furnish and place 48-inch precast concrete covers	each	56.00
Furnish and install 6-inch diameter nozzles	each	150.00
Furnish and install 20-inch nozzle without cover	each	350.00
Furnish and install 20-inch nozzle with cover	each	550.00
Furnish and install 45-inch nozzles	each	800.00
Furnish and install 6-inch globe valves	each	180.00
Furnish and install 6-inch-125 pound gate valve	each	107.00
Furnish and install 20-inch-125 pound gate valve	each	1,800
Furnish and install 45-inch-125 pound gate valve	each	4,500
Furnish and install cast iron pipe and fittings	lb.	0.55
Furnish and install steel pipe and fittings	lb.	0.60
Furnish and install 8-inch air valves	each	400.00

UNIT PRICES USED FOR DETAILED COST ESTIMATES
OF PROPOSED SAN DIEGO AQUEDUCT
"W" LINE
(continued)

Item	: Unit	: Unit price
<u>Pipe Line Construction (continued)</u>		
Furnishing and laying 78-inch concrete pipe:		
Head class 100	lin.ft. \$	51.00
Head class 150	lin.ft.	55.00
Head class 200	lin.ft.	61.00
Head class 250	lin.ft.	66.00
Head class 300	lin.ft.	71.00
Head class 350	lin.ft.	76.00
Head class 400	lin.ft.	81.00
Head class 450	lin.ft.	86.00
Head class 500	lin.ft.	91.00
Furnishing and laying 84-inch concrete pipe:		
Head class 50	lin.ft.	52.00
Head class 100	lin.ft.	57.00
Head class 150	lin.ft.	61.00
Head class 200	lin.ft.	67.00
Head class 250	lin.ft.	73.00
Head class 300	lin.ft.	79.00
Head class 350	lin.ft.	85.00
Head class 400	lin.ft.	91.00
Head class 450	lin.ft.	97.00
Head class 500	lin.ft.	103.00
Furnishing and laying 90-inch concrete pipe:		
Head class 50	lin.ft.	64.00
Head class 100	lin.ft.	69.00
Head class 150	lin.ft.	74.00
Head class 200	lin.ft.	81.00
Head class 250	lin.ft.	89.00
Head class 300	lin.ft.	95.00
Head class 350	lin.ft.	102.00
Head class 400	lin.ft.	109.00
Head class 450	lin.ft.	116.00
Head class 500	lin.ft.	123.00
Furnishing and laying 78-inch steel pipe:		
13/32-inch thick	lin.ft.	63.00
15/32-inch thick	lin.ft.	71.00
17/32-inch thick	lin.ft.	79.00
9/16-inch thick	lin.ft.	83.00
5/8-inch thick	lin.ft.	90.00
11/16-inch thick	lin.ft.	97.00
Furnishing and laying 84-inch steel pipe:		
7/16-inch thick	lin.ft.	72.00
1/2-inch thick	lin.ft.	81.00
9/16-inch thick	lin.ft.	89.00
5/8-inch thick	lin.ft.	96.00
11/16-inch thick	lin.ft.	104.00

UNIT PRICES USED FOR DETAILED COST ESTIMATES
OF PROPOSED SAN DIEGO AQUEDUCT
"W" LINE
(continued)

Item	: Unit	: Unit price
<u>Pipe Line Construction (continued)</u>		
Furnishing and laying 84-inch steel pipe (continued)		
3/4-inch thick	lin.ft. \$	110.00
13/16-inch thick	lin.ft.	119.00
7/8-inch thick	lin.ft.	128.00
15/16-inch thick	lin.ft.	134.00
1-inch thick	lin.ft.	143.00
1-1/16-inch thick	lin.ft.	151.00
1-1/8-inch thick	lin.ft.	159.00
1-3/16-inch thick	lin.ft.	167.00
Furnishing and laying 90-inch steel pipe:		
15/32-inch thick	lin.ft.	79.00
17/32-inch thick	lin.ft.	87.00
19/32-inch thick	lin.ft.	96.00
21/32-inch thick	lin.ft.	104.00

APPENDIX D

ESTIMATED COST OF INITIAL FEATURES OF
PROPOSED SAN DIEGO AQUEDUCT FROM SAN
JACINTO TUNNEL TO MINNEWAWA RESERVOIR
"W" LINE

SUMMARY OF
ESTIMATED COST OF INITIAL FEATURES OF
PROPOSED SAN DIEGO AQUEDUCT FROM SAN
JACINTO TUNNEL TO MINNEWAWA RESERVOIR
"W" LINE

(Based on prices prevailing in the fall of 1956)

Station	:	Item	:	Cost
0+00 to 17+50		San Jacinto Tunnel to Beginning of Canal, Capacity 1,000 cfs	\$	872,600
17+50 to 1202+00		From Beginning of Canal to Auld Valley Reservoir, Capacity 1,000 cfs		6,246,000
		Auld Valley Reservoir, Capacity 38,000 acre-feet		4,701,600
1202+00 to 1245+50		Auld Valley Reservoir By-Pass Siphon, Capacity 442 cfs		218,800
1245+50 to 1586+75		From Auld Valley to Beginning of Pipe Line, Canal Capacity 884 cfs		2,633,600
1586+75 to 2100+00		Pipe Line from End of Canal to Vallecitos Reservoir Turnout, Capacity 432 cfs		5,205,600
2100+00 to 2721+00		Turnout (Vallecitos Reservoir) to Turnout (Oceanside), Capacity 394 cfs		7,620,900
2721+00 to 2945+00		Turnout (Oceanside) to Turnout (Buena Colorado), Capacity 383 cfs		2,286,800
2945+00 to 3163+00		Turnout (Buena Colorado) to Turnout (Carlsbad), Capacity 374 cfs		2,258,000
3163+00 to 3269+00		Turnout (Carlsbad) to Turnout (San Marcos Reservoir), Capacity 364 cfs		1,182,700
3269+00 to 3861+00		Turnout (San Marcos Reservoir) to Turnout (East of Del Mar), Capacity 335 cfs		6,713,800
3861+00 to 4043+00		Turnout (East of Del Mar) to Turnout (Carroll Reservoir), Capacity 324 cfs		1,849,000
4043+00 to 4214+00		Turnout (Carroll Reservoir) to Turnout (Camp Elliott), Capacity 294 cfs		1,778,200
4214+00 to 4614+00		Turnout (Camp Elliott) to Turnout (San Diego and Helix), Capacity 286 cfs		3,524,100

SUMMARY OF
ESTIMATED COST OF INITIAL FEATURES OF
PROPOSED SAN DIEGO AQUEDUCT FROM SAN
JACINTO TUNNEL TO MINNEWAWA RESERVOIR
"W" LINE
(continued)

Station	:	Item	:	Cost
4614+00 to 4995+00		Turnout (San Diego and Helix) to Turnout (South Bay and National City), Capacity 157 cfs		\$ 3,557,300
4995+00 to 5274+00		Turnout (South Bay and National City) to Turnout (Otay and Imperial),		2,406,000
5274+00 to 5522+00		Turnout (Otay and Imperial) to Minnewawa Reservoir, Capacity 98 cfs		<u>1,963,600</u>
Subtotal				\$55,018,600
Administration and engineering, 10%				5,501,900
Contingencies, 15%				8,252,800
Interest during construction				<u>3,111,500</u>
TOTAL				\$71,884,800

ESTIMATED COST OF INITIAL FEATURES OF
PROPOSED SAN DIEGO AQUEDUCT FROM SAN
JACINTO TUNNEL TO MINNEWAWA RESERVOIR
"W" LINE

(Based on prices prevailing in the fall of 1956)

Item	: Unit	: Quantity	: Unit price	: Cost
<u>Sta. 0+00 to Sta. 17+50</u>				
<u>San Jacinto Tunnel to Beginning of Canal, Capacity 1,000 cfs</u>				
<u>Tunnel and Connection to San Jacinto Tunnel</u>				
Excavation	cu.yd.	470	\$ 75.00	\$ 35,250
Removing existing concrete	cu.yd.	25	30.00	750
Concrete in tunnel lining	cu.yd.	140	100.00	14,000
Reinforcing steel	lb.	20,000	0.20	4,000
Diversion of aqueduct flow			lump sum	<u>3,000</u> \$ 57,000
<u>Transition, Gate Section and Flume, Sta. 0+52 to Sta. 4+00</u>				
Structure excavation	cu.yd.	13,200	3.50	46,200
Backfill	cu.yd.	7,000	1.50	10,500
Compacting backfill	cu.yd.	1,850	3.50	6,470
Graded gravel blankets and drains	cu.yd.	410	7.00	2,870
Concrete in structures	cu.yd.	810	75.00	60,750
Reinforcing steel	lb.	122,000	0.16	19,520
Radial gate and hoist	each	1	12,680	12,680
6-foot chain link fence	lin.ft.	725	1.75	1,270
6-inch pipe under drains	lin.ft.	350	2.00	<u>700</u> 160,960
<u>13'-0" I.D. Monolithic Concrete Siphons, Sta. 4+00 to Sta. 4+80 and Sta. 6+72 to Sta. 17+50</u>				
Structure excavation	cu.yd.	39,000	3.00	117,000
Backfill	cu.yd.	30,000	0.70	21,000
Compacting backfill	cu.yd.	300	3.50	1,050
Concrete in structures	cu.yd.	2,330	75.00	174,750
Reinforcing steel	lb.	215,000	0.16	34,400
Riprap	cu.yd.	660	9.00	<u>5,940</u> 354,140

ESTIMATED COST OF INITIAL FEATURES OF
PROPOSED SAN DIEGO AQUEDUCT FROM SAN
JACINTO TUNNEL TO MINNEWAWA RESERVOIR
"W" LINE
(continued)

Item	Unit	Quantity	Unit price	Cost
<u>Sta. 0+00 to Sta. 17+50 (continued)</u>				
Steel Pipe, Metering and Control Station, Sta. 4+80 to Sta. 6+72				
Structure excavation	cu.yd.	18,000	\$ 3.00	\$ 54,000
Backfill	cu.yd.	11,000	0.70	7,700
Compacting backfill	cu.yd.	1,650	3.50	5,780
Concrete in structures	cu.yd.	475	75.00	35,620
Reinforcing steel	lb.	50,000	0.16	8,000
Steel piping	lb.	196,000	0.40	78,400
Venturi meters, 120-inch and 60-inch			lump sum	50,000
30-inch cone valve	each	1	19,400	19,400
60-inch cone valve	each	1	37,900	37,900
Electrical installation			lump sum	1,500
Sump pump	each	1	300	300
Gravel blankets and drains	cu.yd.	130	7.00	<u>910</u>
				\$ 299,510
<u>Right of Way</u>			lump sum	<u>1,000</u>
Subtotal				\$ 872,600

Sta. 17+50 to Sta. 1202+00
From Beginning of Canal to Auld Valley Reservoir, Capacity 1,000 cfs

Earthwork, Concrete Lining, Fences and Underdrains

Excavation for canal				
Common	cu.yd.	1,330,000	0.25	332,500
Rock	cu.yd.	714,000	1.90	1,356,600
Excavation for drainage channels				
	cu.yd.	147,000	0.40	58,800
Compacting embankments	cu.yd.	194,000	0.45	87,300
Backfill over canal lining	cu.yd.	34,300	1.30	44,590
Trimming earth foundations for concrete lining				
	sq.yd.	550,700	0.50	275,350
Preparing rock foundations for concrete lining				
	sq.yd.	177,400	1.70	301,580
4-inch gravel blanket for canal underdrains	sq.yd.	86,000	1.25	107,500

ESTIMATED COST OF INITIAL FEATURES OF
PROPOSED SAN DIEGO AQUEDUCT FROM SAN
JACINTO TUNNEL TO MINNEWAWA RESERVOIR
"W" LINE
(continued)

Item	Unit	Quantity	Unit price	Cost
<u>Sta. 17+50 to Sta. 1202+00 (continued)</u>				
<u>Earthwork, Concrete Lining, Fences and Underdrains (continued)</u>				
Flap valve weeps	each	3,700	\$ 7.50	\$ 27,750
Concrete lining	cu.yd.	71,650	23.50	1,683,780
Safety ladders	lb.	9,250	0.35	3,240
Gravel on operating road	cu.yd.	15,300	4.00	61,200
6-foot chain link fence	lin.ft.	110,200	1.75	192,850
Barbed wire fence	mi.	21.9	2,500	54,750
Steel gates	each	120	50.00	6,000
Aqueduct crossing sta. 521+98			lump sum	10,000
				\$ 4,603,800
<u>Concrete Bridges (10)</u>				
Structure excavation	cu.yd.	1,960	1.25	2,450
Backfill	cu.yd.	2,410	0.70	1,690
Compacting backfill	cu.yd.	2,410	3.50	8,440
Compacting road embankments	cu.yd.	2,470	1.00	2,470
Bituminous road surfacing	sq.yd.	4,380	3.00	13,140
Concrete	cu.yd.	1,395	85.00	118,580
Reinforcing steel	lb.	222,400	0.16	35,580
Steel guard railing	lin.ft.	1,250	8.00	10,000
				192,400
<u>Timber Bridges (25)</u>				
Structure excavation	cu.yd.	4,100	1.25	5,130
Backfill	cu.yd.	3,000	0.70	2,100
Compacting backfill	cu.yd.	3,000	3.50	10,500
Concrete	cu.yd.	250	85.00	21,250
Reinforcing steel	lb.	27,500	0.16	4,400
Compacting embankments	cu.yd.	1,500	1.00	1,500
Gravel road surfacing	cu.yd.	190	4.00	760
Untreated timber	M.B.M.	230	340.00	78,200
Treated timber	M.B.M.	29	405.00	11,750
				135,600
<u>Turnouts (4)</u>				
Structure excavation	cu.yd.	1,520	1.25	1,900
Backfill	cu.yd.	1,220	0.70	850
Compacting backfill	cu.yd.	1,220	3.50	4,270
Concrete	cu.yd.	60	85.00	5,100
Reinforcing steel	lb.	5,800	0.16	930
24-inch reinforced concrete pipe	lin.ft.	56	6.75	380

ESTIMATED COST OF INITIAL FEATURES OF
PROPOSED SAN DIEGO AQUEDUCT FROM SAN
JACINTO TUNNEL TO MINNEWAWA RESERVOIR
"W" LINE
(continued)

Item	Unit	Quantity	Unit price	Cost
<u>Sta. 17+50 to Sta. 1202+00 (continued)</u>				
<u>Turnouts (4) (continued)</u>				
42-inch reinforced concrete pipe	lin.ft.	56	\$ 15.00	\$ 840
48-inch reinforced concrete pipe	lin.ft.	112	18.00	2,020
24-inch cast iron slide gate	each	1	236.00	240
42-inch cast iron slide gate	each	1	470.00	470
48-inch cast iron slide gate	each	2	635.00	1,270
66-inch cast iron slide gate	each	1	1,500	<u>1,500</u>
				\$ 19,800
<u>Culverts (12)</u>				
Structure excavation				
Common	cu.yd.	1,120	1.25	1,400
Rock	cu.yd.	350	4.50	1,580
Backfill	cu.yd.	1,160	0.70	810
Compacting backfill	cu.yd.	1,000	3.50	3,500
Concrete	cu.yd.	144	85.00	12,240
Reinforcing steel	lb.	16,710	0.16	2,670
18-inch reinforced concrete pipe	lin.ft.	700	6.00	4,200
24-inch reinforced concrete pipe	lin.ft.	700	6.75	4,730
30-inch reinforced concrete pipe	lin.ft.	560	10.00	5,600
Riprap	cu.yd.	60	9.00	<u>540</u>
				37,300
<u>Pipe Overchutes (44)</u>				
Structure excavation	cu.yd.	3,740	1.25	4,680
Backfill	cu.yd.	6,160	0.70	4,310
Compacting backfill	cu.yd.	6,160	3.50	21,560
Concrete	cu.yd.	350	85.00	29,750
Reinforcing steel	lb.	28,900	0.16	4,620
18-inch C.M.P., 12 ga.	lin.ft.	560	7.50	4,200
24-inch C.M.P., 12 ga.	lin.ft.	400	9.50	3,800
30-inch C.M.P., 12 ga.	lin.ft.	400	11.50	4,600
36-inch C.M.P., 12 ga.	lin.ft.	400	15.60	6,240
18-inch welded steel pipe, 10 ga.	lin.ft.	786	11.00	8,650
24-inch welded steel pipe, 10 ga.	lin.ft.	560	16.80	<u>9,410</u>

ESTIMATED COST OF INITIAL FEATURES OF
PROPOSED SAN DIEGO AQUEDUCT FROM SAN
JACINTO TUNNEL TO MINNEWAWA RESERVOIR
"W" LINE
(continued)

Item	Unit	Quantity	Unit price	Cost
<u>Sta. 17+50 to Sta. 1202+00 (continued)</u>				
<u>Pipe Overchutes (44) (continued)</u>				
30-inch welded steel pipe, 10 ga.	lin.ft.	560	\$ 21.05	\$ 11,790
36-inch welded steel pipe, 10 ga.	lin.ft.	560	27.30	15,290
Couplings and stiffeners	lb.	8,200	0.65	5,330
Riprap	cu.yd.	260	9.00	<u>2,340</u>
				\$ 136,600
<u>Flume Overchutes (18)</u>				
Structure excavation	cu.yd.	10,510	1.25	13,140
Backfill	cu.yd.	6,300	0.70	4,410
Compacting backfill	cu.yd.	6,300	3.50	22,050
Concrete	cu.yd.	1,185	85.00	100,730
Reinforcing steel	lb.	190,730	0.16	30,520
Riprap	cu.yd.	110	9.00	<u>990</u>
				171,800
<u>Irrigation Crossings (31)</u>				
Structure excavation	cu.yd.	2,640	1.25	3,300
Backfill	cu.yd.	4,340	0.70	3,040
Compacting backfill	cu.yd.	4,000	3.50	14,000
Concrete	cu.yd.	280	85.00	23,800
Reinforcing steel	lb.	23,250	0.16	3,720
18-inch reinforced concrete pipe	lin.ft.	1,240	6.00	7,440
18-inch welded steel pipe, 10 ga.	lin.ft.	1,730	11.00	19,030
Couplings and stiffeners	lb.	3,300	0.65	<u>2,150</u>
				76,500
<u>Check Structures (2)</u>				
Structure excavation	cu.yd.	3,040	1.25	3,800
Concrete	cu.yd.	637	85.00	54,150
Reinforcing steel	lb.	20,000	0.16	3,200
16' x 11' radial gate and hoist	each	2	13,200	<u>26,400</u>
				87,600
<u>Siphons (6)</u>				
Structure excavation	cu.yd.	57,300	1.25	71,630
Backfill	cu.yd.	40,380	0.70	28,270
Compacting backfill	cu.yd.	4,250	3.50	14,880
Concrete	cu.yd.	4,530	85.00	385,050
Reinforcing steel	lb.	655,000	0.16	<u>104,800</u>
				604,600
<u>Right of Way</u>				<u>180,000</u>
Subtotal				\$ 6,246,000

ESTIMATED COST OF INITIAL FEATURES OF
PROPOSED SAN DIEGO AQUEDUCT FROM SAN
JACINTO TUNNEL TO MINNEWAWA RESERVOIR
"W" LINE
(continued)

Item	Unit	Quantity	Unit price	Cost
<u>Auld Valley Reservoir, Capacity 38,000 Acre-Feet</u>				
Dam and Reservoir (See appendix for cost breakdown)			lump sum	\$ 4,701,600
<u>Sta. 1202+00 to Sta. 1245+50</u>				
<u>Auld Valley Reservoir By-Pass Siphon, Capacity 442 cfs</u>				
<u>Siphon</u>				
Excavation	cu.yd.	30,900	\$ 1.50	\$ 46,350
Backfill	cu.yd.	24,750	0.65	16,090
Consolidating backfill	cu.yd.	810	2.50	2,030
66-inch reinforced concrete pipe	lin.ft.	4,350	34.65	150,730
14-inch pipe vent	each	1	400.00	400
Blowoff	each	1	3,200	3,200
				<u>218,800</u>
Subtotal				\$ 218,800
<u>Sta. 1245+50 to Sta. 1586+75 from Auld Valley to Beginning of Pipe Line, Canal Capacity 884 cfs</u>				
<u>Earthwork, Concrete Lining, and Fences</u>				
<u>Excavation for canal</u>				
Common	cu.yd.	486,000	0.25	121,500
Rock	cu.yd.	322,000	2.70	869,400
Excavation for drainage channels	cu.yd.	39,000	0.40	15,600
Trimming earth foundations for concrete lining	sq.yd.	161,200	0.50	80,600
Preparing rock foundations for concrete lining	sq.yd.	26,500	1.70	45,050
Compacting embankments	cu.yd.	50,000	0.45	22,500
Backfill over canal lining	cu.yd.	9,100	1.30	11,830
Concrete lining	cu.yd.	18,100	23.50	425,350
Gravel on operating road	cu.yd.	3,240	4.00	12,960
Safety ladders	lb.	2,550	0.35	890
4-strand barbed wire fence	mi.	11.65	2,500	29,130
6-foot chain link fence	lin.ft.	500	1.75	880
				<u>1,635,700</u>

ESTIMATED COST OF INITIAL FEATURES OF
PROPOSED SAN DIEGO AQUEDUCT FROM SAN
JACINTO TUNNEL TO MINNEWAWA RESERVOIR
"W" LINE
(continued)

Item	: Unit	: Quantity	: Unit price	: Cost
<u>Sta. 1245+50 to Sta. 1586+75 (continued)</u>				
<u>Timber Bridges (3)</u>				
Structure excavation	cu.yd.	500	\$ 1.25	\$ 630
Backfill	cu.yd.	360	0.70	250
Compacting backfill	cu.yd.	360	3.50	1,260
Compacting embankments	cu.yd.	180	1.00	180
Structure concrete	cu.yd.	40	85.00	3,400
Reinforcing steel	lb.	5,800	0.16	930
Gravel road surfacing	cu.yd.	23	4.00	90
Untreated timber	M.B.M.	45	340.00	15,300
Treated timber	M.B.M.	4	405.00	<u>1,620</u>
				\$ 23,700
<u>Check Structures (3)</u>				
Structure excavation	cu.yd.	3,900	1.25	4,880
Backfill	cu.yd.	2,250	0.70	1,580
Compact backfill	cu.yd.	2,250	3.50	7,880
Concrete	cu.yd.	275	85.00	23,380
Reinforcing steel	lb.	37,500	0.16	6,000
12' x 10' radial gate and hoist	each	3	9,000	27,000
Steel trash rack	lb.	5,000	0.65	<u>3,250</u>
				74,000
<u>Turnouts (2)</u>				
Structure excavation	cu.yd.	600	1.25	750
Backfill	cu.yd.	560	0.70	390
Compacting backfill	cu.yd.	560	3.50	1,960
Concrete	cu.yd.	25	85.00	2,130
Reinforcing steel	lb.	3,200	0.16	510
24-inch reinforced concrete pipe	lin.ft.	16	6.75	110
36-inch reinforced concrete pipe	lin.ft.	16	12.50	200
24-inch cast iron slide gate	each	1	236.00	240
36-inch cast iron slide gate	each	1	400.00	<u>400</u>
				6,700
<u>Flume Overchutes (4)</u>				
Structure excavation	cu.yd.	1,700	1.25	2,130
Backfill	cu.yd.	1,380	0.70	970
Compacting backfill	cu.yd.	1,380	3.50	4,830
Concrete	cu.yd.	250	85.00	21,250
Reinforcing steel	lb.	37,350	0.16	5,980
Riprap	cu.yd.	24	9.00	<u>220</u>
				35,400

ESTIMATED COST OF INITIAL FEATURES OF
PROPOSED SAN DIEGO AQUEDUCT FROM SAN
JACINTO TUNNEL TO MINNEAWA RESERVOIR
"W" LINE
(continued)

Item	Unit	Quantity	Unit price	Cost
<u>Sta. 1245+50 to Sta. 1586+75 (continued)</u>				
<u>Pipe Overchutes (11)</u>				
Structure excavation	cu.yd.	935	\$ 1.25	\$ 1,170
Backfill	cu.yd.	1,540	0.70	1,080
Compacting backfill	cu.yd.	1,540	3.50	5,390
Concrete	cu.yd.	85	85.00	7,230
Reinforcing steel	lb.	7,060	0.16	1,130
18-inch C.M.P., 12 ga.	lin.ft.	160	7.50	1,200
24-inch C.M.P., 12 ga.	lin.ft.	120	9.50	1,140
30-inch C.M.P., 12 ga.	lin.ft.	80	11.50	920
36-inch C.M.P., 12 ga.	lin.ft.	80	15.60	1,250
18-inch welded steel pipe, 10 ga.	lin.ft.	224	11.00	2,460
24-inch welded steel pipe, 10 ga.	lin.ft.	168	16.80	2,820
30-inch welded steel pipe, 10 ga.	lin.ft.	112	21.05	2,360
36-inch welded steel pipe, 10 ga.	lin.ft.	112	27.30	3,060
Couplings and stiffeners	lb.	1,928	0.65	1,250
Riprap	cu.yd.	66	9.00	<u>590</u>
				\$ 33,100
<u>Culverts (5)</u>				
Structure excavation				
Common	cu.yd.	325	1.25	410
Rock	cu.yd.	75	4.50	340
Backfill	cu.yd.	300	0.70	210
Compacting backfill	cu.yd.	300	3.50	1,050
Concrete	cu.yd.	38	85.00	3,230
Reinforcing steel	lb.	3,350	0.16	540
18-inch reinforced concrete pipe	lin.ft.	280	6.00	1,680
24-inch reinforced concrete pipe	lin.ft.	420	6.75	2,840
Riprap	cu.yd.	30	9.00	<u>270</u>
				10,600
<u>Siphons</u>				
Structure excavation	cu.yd.	80,510	1.25	100,640
Backfill	cu.yd.	56,960	0.70	39,870
Compacting backfill	cu.yd.	6,170	3.50	21,600
Concrete	cu.yd.	710	85.00	60,350
Reinforcing steel	lb.	101,200	0.16	16,190

ESTIMATED COST OF INITIAL FEATURES OF
PROPOSED SAN DIEGO AQUEDUCT FROM SAN
JACINTO TUNNEL TO MINNEWAWA RESERVOIR
"W" LINE
(continued)

Item	: Unit	: Quantity	: Unit price	: Cost
<u>Sta. 1245+50 to Sta. 1586+75 (continued)</u>				
<u>Siphons (continued)</u>				
6-foot chain link fence	lin.ft.	100	\$ 1.75	\$ 180
120-inch reinforced concrete pipe	lin.ft.	4,960	110.00	<u>545,600</u> \$ 784,400
<u>Right of Way</u>			lump sum	<u>30,000</u>
Subtotal				\$ 2,633,600

Sta. 1586+75 to Sta. 2100+00
Pipe Line from End of Canal to
Vallecitos Reservoir Turnout, Capacity 432 cfs

<u>Pipe Line</u>				
Excavation				
Common	cu.yd.	217,135	1.20	260,560
Rock	cu.yd.	115,290	3.20	368,930
Backfill	cu.yd.	218,490	0.65	142,020
Consolidating backfill	cu.yd.	18,430	2.50	46,080
90-inch reinforced concrete pipe	lin.ft.	51,325	83.10	4,265,110
Manhole	each	6	3,400	20,400
Manhole and blowoff	each	9	3,930	35,370
Manhole and air valve	each	8	3,800	30,400
Vent structure	each	1	6,130	6,130
Turnout	each	2	730.00	1,460
Turnout	each	1	7,170	<u>7,170</u> 5,183,600
<u>Right of Way</u>			lump sum	<u>22,000</u>
Subtotal				\$ 5,205,600

Sta. 2100+00 to Sta. 2721+00
Turnout (Vallecitos Reservoir) to
Turnout (Oceanside), Capacity 394 cfs

<u>Pipe Line</u>				
Excavation				
Common	cu.yd.	162,560	1.70	276,350
Rock	cu.yd.	249,070	2.75	684,940
Backfill	cu.yd.	283,650	0.65	184,370
Consolidating backfill	cu.yd.	24,100	2.50	60,250
84-inch reinforced concrete pipe	lin.ft.	6,300	66.30	417,690

ESTIMATED COST OF INITIAL FEATURES OF
PROPOSED SAN DIEGO AQUEDUCT FROM SAN
JACINTO TUNNEL TO MINNEWAWA RESERVOIR
"W" LINE
(continued)

Item	Unit	Quantity	Unit price	Cost
<u>Sta. 2100+00 to Sta. 2721+00 (continued)</u>				
<u>Pipe Line (continued)</u>				
84-inch steel pipe	lin.ft.	55,800	\$ 102.90	\$5,741,820
Manhole and blowoff	each	23	3,930	90,390
Manhole and air valve	each	20	3,800	76,000
Vent structure	each	2	6,130	12,260
48-inch vent pipe	lin.ft.	800	40.00	32,000
Turnout	each	2	730.00	1,460
Turnout	each	2	7,170	14,340
				\$ 7,591,900
<u>Right of Way</u>			lump sum	29,000
Subtotal				\$ 7,620,900

Sta. 2721+00 to Sta. 2945+00
Turnout (Oceanside) to
Turnout (Bueno Colorado), Capacity 383 cfs

<u>Pipe Line</u>				
<u>Excavation</u>				
Common	cu.yd.	22,920	1.50	34,380
Rock	cu.yd.	121,640	2.50	304,100
Backfill	cu.yd.	94,730	0.65	61,580
Consolidating backfill	cu.yd.	10,320	2.50	25,800
90-inch reinforced concrete pipe	lin.ft.	11,500	76.25	876,880
90-inch steel pipe	lin.ft.	10,900	82.10	894,890
Manhole	each	2	3,400	6,800
Manhole and blowoff	each	8	3,930	31,440
Manhole and air valve	each	7	3,800	26,600
Vent structure	each	1	6,130	6,130
Turnout	each	1	7,170	7,170
				2,275,800
<u>Right of Way</u>			lump sum	11,000
Subtotal				\$ 2,286,800

Sta. 2945+00 to Sta. 3163+00
Turnout (Bueno Colorado) to
Turnout (Carlsbad), Capacity 374 cfs

<u>Pipe Line</u>				
<u>Excavation</u>				
Common	cu.yd.	63,990	0.50	32,000
Rock	cu.yd.	75,420	2.50	188,550

ESTIMATED COST OF INITIAL FEATURES OF
PROPOSED SAN DIEGO AQUEDUCT FROM SAN
JACINTO TUNNEL TO MINNEWAWA RESERVOIR
"W" LINE
(continued)

Item	: Unit	: Quantity	: Unit price	: Cost
<u>Sta. 2945+00 to Sta. 3163+00 (continued)</u>				
<u>Pipe Line (continued)</u>				
Backfill	cu.yd.	96,900	\$ 0.65	\$ 62,980
Consolidating backfill	cu.yd.	8,440	2.50	21,100
90-inch reinforced concrete pipe	lin.ft.	4,000	78.90	315,600
90-inch steel pipe	lin.ft.	8,500	84.20	715,700
84-inch steel pipe	lin.ft.	9,300	91.65	852,300
Manhole	each	3	3,400	10,200
Manhole and blowoff	each	5	3,930	19,650
Manhole and air valve	each	6	3,800	22,800
Turnout	each	1	7,170	<u>7,170</u>
				\$ 2,248,000
<u>Right of Way</u>			lump sum	<u>10,000</u>
Subtotal				\$ 2,258,000

Sta. 3163+00 to Sta. 3269+00
Turnout (Carlsbad) to
Turnout (San Marcos Reservoir), Capacity 364 cfs

<u>Pipe Line</u>				
Excavation				
Common	cu.yd.	84,870	0.50	42,440
Rock	cu.yd.	48,270	3.65	176,190
Backfill	cu.yd.	83,970	0.65	54,580
Consolidating backfill	cu.yd.	4,020	2.50	10,050
84-inch reinforced concrete pipe	lin.ft.	4,150	59.00	244,850
84-inch steel pipe	lin.ft.	6,450	95.20	614,040
Manhole	each	2	3,400	6,800
Manhole and blowoff	each	3	3,930	11,790
Manhole and air valve	each	1	3,800	3,800
Vent structure	each	1	6,130	6,130
Turnout	each	1	7,170	<u>7,170</u>
				1,177,800
<u>Right of Way</u>			lump sum	<u>4,900</u>
Subtotal				\$ 1,182,700

ESTIMATED COST OF INITIAL FEATURES OF
PROPOSED SAN DIEGO AQUEDUCT FROM SAN
JACINTO TUNNEL TO MINNEWAWA RESERVOIR
"W" LINE
(continued)

Item	: Unit	: Quantity	: price	: Unit	: Cost
Sta. 3269+00 to Sta. 3861+00 Turnout (San Marcos Reservoir) to Turnout (East of Del Mar), Capacity 335 cfs					
<u>Pipe Line</u>					
Excavation					
Common	cu.yd.	247,970	\$ 1.40	\$	347,160
Rock	cu.yd.	160,580	2.60		417,510
Backfill	cu.yd.	280,900	0.65		182,590
Consolidating backfill	cu.yd.	19,280	2.50		48,200
90-inch reinforced concrete pipe	lin.ft.	10,250	91.00		932,750
90-inch steel pipe	lin.ft.	13,000	79.00		1,027,000
84-inch reinforced concrete pipe	lin.ft.	6,450	82.90		534,710
84-inch steel pipe	lin.ft.	30,100	100.25		3,017,530
Manhole	each	3	3,400		10,200
Manhole and blowoff	each	18	3,930		70,740
Manhole and air valve	each	17	3,800		64,600
Vent structure	each	2	6,130		12,260
Turnout	each	3	7,170		21,510
					\$ 6,686,800
<u>Right of Way</u>			lump sum		27,000
Subtotal					\$ 6,713,800

Sta. 3861+00 to Sta. 4043+00
Turnout (East of Del Mar) to
Turnout (Carroll Reservoir), Capacity 324 cfs

<u>Pipe Line</u>					
Excavation					
Common	cu.yd.	46,890	1.00		46,890
Rock	cu.yd.	72,550	3.00		217,650
Backfill	cu.yd.	81,570	0.65		53,020
Consolidating backfill	cu.yd.	7,430	2.50		18,580
90-inch reinforced concrete pipe	lin.ft.	8,800	77.20		679,360
84-inch reinforced concrete pipe	lin.ft.	9,400	80.60		757,640
Manhole and blowoff	each	7	3,930		27,510
Manhole and air valve	each	7	3,800		26,600
Vent structure	each	1	6,130		6,130
Turnout	each	1	7,170		7,170
					1,840,600

ESTIMATED COST OF INITIAL FEATURES OF
PROPOSED SAN DIEGO AQUEDUCT FROM SAN
JACINTO TUNNEL TO MINNEWAWA RESERVOIR
"W" LINE
(continued)

Item	: Unit	: Quantity	: Unit price	: Cost
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Sta. 3861+00 to Sta. 4043+00 (continued)

<u>Right of Way</u>			lump sum	\$ 8,400
Subtotal				\$ 1,849,000

Sta. 4043+00 to Sta. 4214+00
Turnout (Carroll Reservoir) to
Turnout (Camp Elliott), Capacity 294 cfs

Pipe Line

Excavation				
Common	cu.yd.	102,910	\$ 1.00	\$ 102,910
Rock	cu.yd.	15,850	3.00	47,550
Backfill	cu.yd.	81,710	0.65	53,110
Consolidating backfill	cu.yd.	5,080	2.50	12,700
90-inch reinforced concrete pipe	lin.ft.	17,100	86.40	1,477,440
Manhole and blowoff	each	9	3,930	35,370
Manhole and air valve	each	9	3,800	34,200
Turnout	each	1	7,170	7,170
				1,770,400

<u>Right of Way</u>			lump sum	7,800
Subtotal				\$ 1,778,200

Sta. 4214+00 to Sta. 4614+00
Turnout (Camp Elliott) to
Turnout (San Diego and Helix), Capacity 286 cfs

Pipe Line

Excavation				
Common	cu.yd.	242,660	1.00	242,660
Rock	cu.yd.	22,970	3.50	80,400
Backfill	cu.yd.	187,630	0.65	121,960
Consolidating backfill	cu.yd.	10,880	2.50	27,200
84-inch reinforced concrete pipe	lin.ft.	33,750	70.75	2,387,810
84-inch steel pipe	lin.ft.	6,250	81.45	509,060
Manhole	each	1	3,400	3,400
Manhole and blowoff	each	16	3,930	62,880
Manhole and air valve	each	15	3,800	57,000
Vent structure	each	1	6,130	6,130
Turnout	each	1	7,170	7,170
				3,505,700

ESTIMATED COST OF INITIAL FEATURES OF
PROPOSED SAN DIEGO AQUEDUCT FROM SAN
JACINTO TUNNEL TO MINNEWAWA RESERVOIR
"W" LINE
(continued)

Item	: Unit	: Quantity	: price	: Unit	: Cost
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Sta. 4214+00 to Sta. 4614+00 (continued)

<u>Right of Way</u>				lump sum	\$ 18,400
Subtotal					\$ 3,524,100

Sta. 4614+00 to Sta. 4995+00
Turnout (San Diego and Helix) to

Turnout (South Bay and National City), Capacity 157 cfs

<u>Pipe Line</u>					
Excavation					
Common	cu.yd.	196,790	\$ 1.00	\$ 196,790	
Rock	cu.yd.	37,030	3.50	129,610	
Backfill	cu.yd.	170,240	0.65	110,660	
Consolidating backfill	cu.yd.	10,950	2.50	27,380	
Construction in street	lin.ft.	19,500	10.00	195,000	
78-inch steel pipe	lin.ft.	38,100	70.85	2,699,390	
Murray turnout					
control station			lump sum	112,600	
Manhole	each	10	3,400	34,000	
Manhole and blowoff	each	4	3,930	15,720	
Manhole and air valve	each	3	3,800	11,400	
Turnout	each	1	7,170	7,170	3,539,700
<u>Right of Way</u>				lump sum	17,600
Subtotal					\$ 3,557,300

Sta. 4995+00 to Sta. 5274+00

Turnout (South Bay and National City) to
Turnout (Otay and Imperial), Capacity 144 cfs

<u>Pipe Line</u>					
Excavation					
Common	cu.yd.	274,300	0.90	246,870	
Rock	cu.yd.	5,930	3.50	20,760	
Backfill	cu.yd.	132,890	0.65	86,380	
Consolidating backfill	cu.yd.	7,410	2.50	18,530	
Prepare subgrade and surface road	sq.yd.	4,670	5.00	23,350	
78-inch reinforced concrete pipe	lin.ft.	15,150	57.90	877,190	
78-inch steel pipe	lin.ft.	12,750	79.35	1,011,710	
48-inch reinforced concrete pipe	lin.ft.	550	40.00	22,000	

ESTIMATED COST OF INITIAL FEATURES OF
PROPOSED SAN DIEGO AQUEDUCT FROM SAN
JACINTO TUNNEL TO MINNEWAWA RESERVOIR
"W" LINE
(continued)

Item	Unit	Quantity	Unit price	Cost
<u>Sta. 4995+00 to Sta. 5274+00 (continued)</u>				
<u>Pipe Line (continued)</u>				
Manhole	each	1	\$ 3,400	\$ 3,400
Manholes and blowoffs	each	8	3,930	31,440
Manholes and air valves	each	8	3,800	30,400
Vent structure	each	1	7,170	7,170
Turnout	each	1	14,000	<u>14,000</u>
				\$ 2,393,200
<u>Right of Way</u>			lump sum	<u>12,800</u>
Subtotal				\$ 2,406,000

Sta. 5274+00 to Sta. 5522+00
Turnout (Otay and Imperial) to
Minnewawa Reservoir, Capacity 98 cfs

<u>Pipe Line</u>				
Excavation				
Common	cu.yd.	34,080	1.00	34,080
Rock	cu.yd.	102,820	2.00	205,640
Backfill	cu.yd.	95,000	0.65	61,750
Consolidating backfill	cu.yd.	11,250	2.50	28,130
78-inch steel pipe	lin.ft.	24,600	63.00	1,549,800
Manholes	each	2	3,400	6,800
Manholes and blowoffs	each	9	3,930	35,370
Manholes and air valves	each	8	3,800	<u>30,400</u>
				1,952,000
<u>Right of Way</u>			lump sum	<u>11,600</u>
Subtotal				\$ 1,963,600

APPENDIX E

DESCRIPTION OF PROPOSED DAMS AND RESERVOIRS NEEDED TO PROVIDE REGULATORY AND EMERGENCY STORAGE ON THE PROPOSED AND EXISTING SAN DIEGO AQUEDUCTS

Auld Valley Dam and Reservoir

Minnewawa Dam and Reservoir

Vallecitos Dam and Reservoir

San Marcos Dam and Reservoir

Woodson Dam and Reservoir

Carroll Dam and Reservoir

Enlargement of San Vicente Reservoir

Enlargement of Lower Otay Reservoir

Auld Valley Dam and Reservoir

The Auld Valley dam site is located on Tucalota Creek along the west line of Sec. 2, T. 7 S., R. 2 W., S.B.B. & M. Stream bed elevation is about 1,400 feet, U.S.G.S. datum.

The Auld Valley dam site was mapped at a scale of 1 inch equals 200 feet with a contour interval of 10 feet by the Department of Water Resources in 1956. Reservoir areas and storage capacities for various stages of water surface elevation were obtained by planimetering United States Geological Survey quadrangles at a scale of 1:24,000 with a contour interval of 20 feet, and are shown in Table E-1.

TABLE E-1

AREAS AND CAPACITIES OF AULD VALLEY RESERVOIR

Depth of water at dam, in feet	: Water surface elevation U.S.G.S. datum in feet	: Water surface area, in acres	: Storage capacity in acre-feet
0	1,400	0	0
10	1,410	60	300
20	1,420	140	1,300
30	1,430	250	3,250
40	1,440	380	6,400
50	1,450	510	10,800
60	1,460	640	16,600
70	1,470	810	23,800
80	1,480	990	32,800
85	1,485	1,080	38,000
90	1,490	1,170	43,600
100	1,500	1,350	56,200

A geological reconnaissance of the dam site was made by this Department. The relief at the dam site is relatively low and the abutment slopes are gentle. Topography, foundation conditions, and availability of materials indicate that an earthfill type of dam is feasible at this site.

Rock types are quartzite schist and gabbro of Cretaceous or possibly Triassic age. The gabbro is exposed on the flank of the right abutment and the schist is exposed on the left abutment. The contact between the two rock types was found exposed in the stream channel at the base of the right abutment. The small hill on the right abutment is apparently a pendant of the main schist body which outcrops on the left abutment. Gabbro on the right abutment is a dark bluish grey, massive and very hard, with grain size fine to medium. The schist on the left abutment is layered and broken. The bedrock is slightly veined. Small localized shears were noted in the left abutment.

No faults were noted but regional seismicity is high, the area being approximately eight miles from the Elsinore fault zone.

The right abutment which extends southward has an essentially even slope of about 25 per cent, with outcropping occurring on 10 per cent of the surface. The slope falls away sharply upstream and downstream. There are no breaks in the slope and creep is negligible. The soil mantle is about three feet in thickness and composed of loose weathered rock and soil. Bedrock is moderately weathered and blocky to a depth of five feet. Stripping would be necessary to an average depth of about eight feet.

The left abutment has an uneven slope of about 15 per cent. Of the surface area, about five per cent is gullied. The slope is continuous both up and downstream. There are no breaks in slope and creep is slight. The soil mantle is about five feet thick composed of weathered rock and soil, and the bedrock is weathered and layered to a depth of about 10 feet. Stripping would be necessary to an average depth of about 15 feet.

The channel width is about 2,400 feet with no outcrops. From logs of wells in the vicinity, it is estimated that the channel is filled to a depth of about 100 feet with alluvium consisting of sand, silt and some cobbles. There appears to be a clay stratum about five feet thick at a depth of about 25 feet

underlying the channel. The channel material will probably have to be removed to a depth of about 100 feet and replaced with compacted impervious fill.

Earthfill materials were found to be available near the site in adequate quantity. There are about 2,800,000 cubic yards of impervious material in the stream channel extending upstream from the dam site about two miles. Random fill materials in the amount of about 3,000,000 cubic yards were found in the reservoir area just upstream from the right abutment and on the high ground about one mile upstream from the site in the fork of the stream. In addition, about 488,000 cubic yards of earth material that would be removed from the channel and about 78,000 cubic yards of rock and earth salvaged from the spillway cut could be utilized for random fill. Because of the presence of considerable amounts of clay, the random fill materials are not considered to be free draining. Rock for riprap could be quarried on the flank of Bachelor Mountain within 2,000 feet of the dam site, or obtained from material excavated in the spillway cut.

For the cost estimates, a zoned earthfill structure was selected which would create a reservoir storage capacity of 38,000 acre-feet with a spillway lip elevation of 1,485. The dam would have a height of 100 feet above stream bed, side slopes of 2.5:1 and a crest elevation of 1,500. It would contain approximately 3,072,000 cubic yards of fill. The crest width would be 30 feet, comprised of ten-foot width for the impervious core, and ten-foot widths for each of the upstream and downstream random fill sections. The impervious core section would have upstream and downstream slopes of 1:1. In order to prevent excessive leakage, the impervious core was assumed to extend to bedrock at a maximum depth of 100 feet in the channel. Moderate to light grouting on the abutments was assumed. Since it was found that ground water levels in the channel are within 15 feet of the surface, a well point system would be necessary to accomplish excavation of the core trench.

Because of the need for drainage of the downstream random fill zone, a gravel blanket with a thickness of six feet would be placed on the downstream face of the impervious core extending to a height equal to two-thirds of the distance between stream bed and spillway lip. Seepage from the impervious core and abutment contacts intercepted by the blanket drain would be carried to the downstream toe of the dam by gravel drains. The upstream face of the dam would be protected against wave action by rock riprap to a depth of three feet normal to the slope.

The spillway would be a concrete-lined chute, with ogee weir control section, placed in a cut through a saddle behind the small hill on the right abutment. The maximum depth of cut in the saddle would be 30 feet, with about two feet of soil, three feet of weathered rock and the remainder in massive, slightly blocky and hard gabbro. The spillway would have a discharge capacity of about 19,000 second-feet, the estimated discharge of a once in a thousand year flood modified by the effect of surcharge storage in the reservoir. Depth of water above the spillway lip during maximum flood discharge would be approximately 10 feet and the crest of the dam was assumed to be five feet above this maximum water surface.

Releases from the reservoir would be made through an outlet tower 85 feet in height, equipped with eight high pressure slidegates located at intervals of elevation necessary to permit water to be released from selected levels in the reservoir. The outlet conduit would consist of a 102-inch diameter steel pipe encased in reinforced concrete, founded on bedrock along the left abutment and leading through a control valve house to a stilling basin located at the toe of the dam. At the control valve house the conduit would be divided into two 84-inch pipes each equipped with a 72-inch hollow jet valve and a 72-inch by 40-inch venturi meter. A 12-inch diameter steel pipe equipped with a gate valve and venturi meter would be connected to the main outlet conduit at the

control valve house and would discharge into Tucalota Creek downstream from the dam. The stilling basin at the end of the outlet works would consist of a reinforced concrete rectangular basin 20 feet wide, 32 feet long, and 20 feet deep.

It was estimated that the dam could be constructed over a period of one and one-half years. Stream flow could be diverted through an uncompleted portion of the dam in the channel section during part of the construction period until the outlet works were completed.

Construction of a reservoir in Auld Valley would require the relocation of about 2.5 miles of secondary dirt road and the clearing of a small grove of trees and removal of a light growth of brush.

A detailed cost estimate for Auld Valley Dam and Reservoir is presented in Table E-2. For illustrative purposes, a plan, profile, and section for the dam are shown on Plate 21, entitled "Auld Valley Dam on Tucalota Creek".

TABLE E-2

ESTIMATED COST OF AULD VALLEY DAM AND RESERVOIR
WITH STORAGE CAPACITY OF 38,000 ACRE-FEET

(Based on prices prevailing in 1956)

Elevation of crest of dam: 1,500 feet, U.S.G.S. datum	Capacity of reservoir to crest of spillway: 38,000 acre-feet
Elevation of crest of spillway: 1,485 feet	Capacity of spillway with 5-foot freeboard: 19,000 second-feet
Height of dam to spillway crest, above stream bed: 85 feet	

Item	Unit	Quantity	Unit price	Cost
CAPITAL COSTS				
Dam				
Exploration			lump sum \$	40,000
Diversion of stream and dewatering of foundation			lump sum	70,000
Stripping topsoil	cu.yd.	69,000	\$ 0.40	27,600
Excavation for embankment				
Foundation	cu.yd.	697,300	0.60	418,400
From borrow pits	cu.yd.	2,770,400	0.40	1,108,200
Embankment				
Impervious	cu.yd.	1,594,900	0.16	255,200
Random	cu.yd.	851,200	0.12	102,100
Random, salvage	cu.yd.	566,000	0.15	84,900
Riprap	cu.yd.	78,100	3.50	273,400
Drilling grout holes	lin.ft.	19,800	3.00	59,400
Pressure grouting	cu.ft.	13,200	4.00	52,800
Gravel drains	cu.yd.	60,300	3.50	211,000
				<u>\$2,703,000</u>
Spillway and Inlet				
Excavation, unclassified	cu.yd.	251,400	1.50	377,100
Backfill, compacted	cu.yd.	5,770	3.00	17,300
Concrete				
Weir and cutoff	cu.yd.	800	40.00	32,000
Floor	cu.yd.	4,360	35.00	152,600
Walls	cu.yd.	1,430	45.00	64,400
Reinforcing steel	lbs.	317,800	0.15	47,700
Inlet gate			lump sum	<u>20,000</u>
				711,100
Outlet Works				
Excavation	cu.yd.	9,800	2.00	19,600
Backfill, compacted	cu.yd.	2,500	3.00	7,500
Concrete				
Conduit and collars	cu.yd.	1,140	50.00	57,000
Inlet tower	cu.yd.	680	70.00	47,600
Stilling basin and transition	cu.yd.	120	70.00	8,400
Reinforcing steel	lbs.	172,000	0.15	25,800
Miscellaneous metalwork	lbs.	67,100	0.65	43,600

ESTIMATED COST OF AULD VALLEY DAM AND RESERVOIR
WITH STORAGE CAPACITY OF 38,000 ACRE-FEET
(continued)

Item	Unit	Quantity	Unit price	Cost
CAPITAL COSTS				
Outlet Works (continued)				
Steel pipe, 102-inch dia.	lbs.	176,400	\$ 0.30	\$ 52,900
High pressure slide gates	lbs.	148,000	0.50	74,000
Hollow-jet valves, 72-inch dia.			lump sum	63,800
Venturi meters	each	2	20,000	40,000
Control house			lump sum	10,000
Tucalota Creek outlet			lump sum	<u>3,000</u>
				\$ 453,200
Reservoir				
Land and improvements			lump sum	733,800
Clearing reservoir lands	ac.	1,260	50.00	63,000
Road relocation	mi.	2.5	15,000	<u>37,500</u>
				<u>834,300</u>
Subtotal				\$4,701,600
Administration and engineering, 10%				\$ 470,200
Contingencies, 15%				705,200
Interest during construction				<u>176,300</u>
TOTAL				\$6,053,300

Minnewawa Dam and Reservoir

The Minnewawa dam site is located on Jamul Creek about one mile upstream from Lower Otay Reservoir. It is in the NE $\frac{1}{4}$ of Sec. 4, T. 18 S., R. 1 E., S.B.B. & M. Stream bed elevation is about 525 feet, U.S.G.S. datum. Reservoir areas and capacities for various stages of water surface elevation were obtained by planimetering United States Geological Survey quadrangles at a scale of 1:62,500, with a contour interval of 50 feet, and are presented in Table E-3. A topographic map of the dam site at a scale of 1 inch equals 100 feet, with ten foot contour interval was made by the Division of Water Resources in 1955.

TABLE E-3

AREAS AND CAPACITIES OF MINNEWAWA RESERVOIR

Depth of water at dam, in feet	: Water surface elevation, U.S.G.S. datum in feet	: Water surface area, in acres	: Storage capacity, in acre-feet
0	525	0	0
5	530	1	2
15	540	8	47
25	550	19	180
35	560	46	510
45	570	75	1,110
55	580	110	2,040
65	590	140	3,290
75	600	180	4,890
85	610	220	6,890
95	620	280	9,390
105	630	340	12,500
115	640	410	16,200
125	650	490	20,700
135	660	590	26,100
145	670	680	32,500
155	680	800	39,900
165	690	920	48,500
175	700	1,080	58,500
185	710	1,230	70,000
195	720	1,390	83,100
205	730	1,550	97,800
215	740	1,700	114,100
225	750	1,870	131,900

Based upon a preliminary geological reconnaissance, the Minnewawa dam site is considered suitable for an earthfill or combination earth and rockfill dam. Bedrock is meta-volcanic of the pre-Cretaceous age. It is gray-green in color, hard, and the grain size varies from aphanitic to coarse. Fractures and joints are numerous and extend to a considerable depth. No faults were noted. Small zones of shears were observed. A small talus cone was noted at the base of the right abutment. Regional seismicity is low.

The right abutment has an even slope of about 50 per cent. Outcrops are numerous on the upper part of the slope. The slope is even upstream and downstream with minor breaks. Creep is minor and no slides were apparent. For an earthfill structure, about ten feet of talus plus eight feet of bedrock should be stripped from the abutment.

The left abutment is of an even slope of 40 per cent diminishing both upstream and downstream. Outcrops are numerous and breaks in slope are minor. Minor creep was noted. Necessary stripping on this abutment would include about two feet of soil plus about ten feet of weathered and badly fractured and jointed rock.

The channel is about 150 feet wide with outcrops near the center on the axis. Alluvium is silt, sand, gravel, and boulders to an average depth of about 15 feet with a maximum depth of about 25 feet. Stripping would be necessary to an average depth of about 20 feet, consisting of about 15 feet of unconsolidated material plus about five feet of rock.

Moderate to light grouting along the axis of the dam would be necessary.

A dam with a height of 195 feet above stream bed is required to provide a reservoir storage capacity of 59,000 acre-feet at this site. The dam would be a rolled earthfill type with an impervious core of select material and upstream and downstream sections of random material. It would have a crest elevation of 720 feet and side slopes of 3:1 and contain 2,485,000 cubic yards

of fill. The impervious core would have a slope of 0.75:1 and extend to bedrock. Crest width would be 30 feet, comprised of ten foot widths each for the upstream and downstream random sections and ten feet for the crest of the core section.

Earthfill materials were found to be available near the site in adequate quantity. There are about 1,610,000 cubic yards of impervious material in Dulzura Creek extending upstream from the dam site about four miles. Additional impervious material could be obtained from the upper reaches of Lower Otay Reservoir if the water stage is low. Although adequate quantities of pervious material are not available in the reservoir, approximately 1,880,000 cubic yards of random fill material may be obtained from the hills on the northern edge of Lower Otay Reservoir at a distance of about four miles by road. Additional random fill material is available from the San Diego formation immediately east of Lower Otay Reservoir. About 157,500 cubic yards of material from the foundation excavation and 200,900 cubic yards of material salvaged from the spillway excavation could be utilized for random fill. Rock for riprap could be quarried near the axis or obtained from material excavated in the spillway cut.

Because of the need for drainage of the downstream random fill zone, a gravel blanket with a thickness of six feet would be placed on the downstream face of the impervious core extending to a height equal to two-thirds of the distance between stream bed and spillway lip. Seepage from the impervious core and abutment contacts intercepted by the blanket drain would be carried to the downstream toe of the dam by gravel drains. The upstream face of the dam would be protected from wave action by riprap to a depth of three feet normal to the slope.

The spillway would consist of an ogee weir control section and a concrete-lined apron placed in a cut through a saddle behind the left abutment. The maximum depth of cut in the saddle would be about 35 feet with about 10 feet

being weathered rock and soil and the remainder being blocky and very hard meta-volcanic rock. The spillway would have a discharge capacity of about 49,000 second-feet which is the estimated peak flow of a once in a thousand year flood. Because of the preliminary nature of this design, no consideration was given the effect of surcharge storage in the reservoir on reducing the peak flows over the spillway. The depth of water over the spillway lip during maximum flood discharge would be 15 feet and the crest of the dam was set five feet above this maximum water surface elevation.

Inflows to the reservoir from the proposed San Diego Aqueduct and releases from the reservoir would be controlled by construction of an inclined outlet tower 450 feet in length on the left abutment, equipped with six 48-inch diameter hydraulically operated butterfly valves located at various elevations in order to permit releases from selected levels in the reservoir. The inlet-outlet conduit would be a 78-inch diameter steel pipe encased in reinforced concrete and located along the left abutment. At the downstream toe of the dam the outlet conduit would divide into two 78-inch diameter branches, each equipped with a 48-inch diameter cone valve located in the valve house. One branch would be connected to the 78-inch diameter pipe line of the proposed aqueduct and the other would be bulkheaded off for future connection to a possible second stage barrel of the aqueduct.

Time of construction is estimated to be one year. Stream diversion during construction could be effected through the outlet conduit.

Relocation of about one mile of state highway and a bridge would be required. In addition, the road through Proctor Valley would be improved to compensate for inundation of the road along Dulzura Creek.

A detailed cost estimate of Minnewawa Dam and Reservoir is shown on Table E-4. For illustrative purposes, a plan, profile, and cross section of the proposed dam are shown on Plate 22, entitled "Minnewawa Dam on Jamul Creek".

TABLE E-4

ESTIMATED COST OF MINNEWAWA DAM AND RESERVOIR
WITH STORAGE CAPACITY OF 59,000 ACRE-FEET

(Based on prices prevailing in 1956)

Elevation of crest of dam: 720 feet, U.S.G.S. datum	Capacity of reservoir to crest of spillway: 59,000 acre-feet
Elevation of crest of spillway: 700 feet	Capacity of spillway with 5-foot freeboard: 49,000 second-feet
Height of dam to spillway crest, above stream bed: 175 feet	

Item	Unit	Quantity	Unit price	Cost
CAPITAL COSTS				
Dam				
Exploration			lump sum	\$ 35,000
Diversion of stream and dewatering of foundation			lump sum	15,000
Stripping topsoil	cu.yd.	71,400	\$ 0.50	35,700
Excavation for embankment				
Foundation	cu.yd.	134,870	1.00	134,900
From borrow pits	cu.yd.	813,700	0.55	447,500
From stream bed	cu.yd.	1,518,700	0.40	607,500
Embankment				
Impervious	cu.yd.	707,600	0.16	113,200
Random	cu.yd.	1,320,600	0.14	184,900
Random, salvage	cu.yd.	358,400	0.20	71,700
Riprap	cu.yd.	48,100	4.00	192,400
Drilling grout holes	lin.ft.	12,400	3.00	37,200
Pressure grouting	cu.ft.	8,200	4.00	32,800
Gravel drains	cu.yd.	50,500	3.50	176,800
				<u>\$2,084,600</u>
Spillway				
Excavation, unclassified	cu.yd.	236,300	2.60	614,400
Concrete				
Weir and cutoff	cu.yd.	700	40.00	28,000
Floor	cu.yd.	850	35.00	29,800
Walls	cu.yd.	70	45.00	3,200
Reinforcing steel	lbs.	118,000	0.15	17,700
				<u>693,100</u>
Outlet Works				
Excavation				
Structures	cu.yd.	14,800	2.50	37,000
Conduit	cu.yd.	12,600	2.50	31,500
Backfill	cu.yd.	8,300	2.50	20,800
Concrete				
Conduit and collars	cu.yd.	1,840	50.00	92,000
Inlet structure	cu.yd.	1,510	70.00	105,700
Gate chamber and valve house	cu.yd.	80	80.00	6,400
Reinforcing steel	lbs.	200,000	0.15	30,000
Miscellaneous metalwork	lbs.	23,200	0.65	15,100

ESTIMATED COST OF MINNEWAWA DAM AND RESERVOIR
WITH STORAGE CAPACITY OF 59,000 ACRE-FEET
(continued)

Item	: Unit	: Quantity	: Unit price	: Cost
CAPITAL COSTS				
Outlet Works (continued)				
Steel pipe, 78-inch dia.	lbs.	316,250	\$ 0.30	\$ 94,900
Cone valve, 48-inch dia.	each	2	20,000	40,000
Butterfly valve, 48-inch dia.	each	6	22,500	135,000
Asphalt apron-inlet tower	sq.ft.	42,000	0.20	<u>8,400</u> \$ 616,800
Reservoir				
Land and improvements			lump sum	1,147,000
Clearing reservoir lands	ac.	1,100	50.00	55,000
Road relocation			lump sum	<u>255,000</u> <u>1,457,000</u>
Subtotal				\$4,851,500
Administration and engineering, 10%				\$ 485,200
Contingencies, 15%				727,700
Interest during construction				<u>121,300</u>
TOTAL				\$6,185,700

Vallecitos Dam and Reservoir

The Vallecitos dam site is located on a tributary to the San Luis Rey River in the NW $\frac{1}{4}$ of Sec. 13, T. 9 S., R. 3 W., S.B.B.& M. Stream bed elevation at the site is about 770 feet. Reservoir areas and storage capacities were computed from United States Geological Survey quadrangles at a scale of 1:24,000 with a contour interval of 20 feet and are shown in Table E-5.

TABLE E-5

AREAS AND CAPACITIES OF VALLECITOS RESERVOIR

Depth of water at dam, in feet	: Water surface elevation U.S.G.S. datum in feet	:	Water surface area, in acres	:	Storage capacity in acre-feet
0	770		0		0
10	780		1		5
20	790		3		25
30	800		6		70
40	810		12		160
50	820		20		320
60	830		25		540
70	840		31		820
80	850		40		1,180
90	860		50		1,630
100	870		61		2,180
110	880		76		2,870
120	890		92		3,710
130	900		110		4,720
140	910		120		5,870
150	920		140		7,170
160	930		160		8,670
168	938		180		10,000
170	940		185		10,400

Topography at the site is rough with steep slopes. Based upon preliminary geological reconnaissance made by this Department, the Vallecitos dam site is considered suitable for either a zoned earthfill or rockfill type of structure, or, with more foundation preparation, a masonry dam.

Bedrock at this site is composed of moderately weathered Woodson Mountain granodiorite of the Cretaceous age. It is greyish white in color, moderately hard and of a coarse grain size. The joint system is fairly well developed with exfoliation type joints being most common. A moderate amount of grouting would be required for a grout curtain as the joints appear to close with depth. There are no apparent shears, faults, or slides.

Regional seismicity is active, the site being approximately five miles southwest of the Elsinore fault system.

The right abutment has an average slope of about 75 per cent with outcrops occurring over approximately half the areal extent of the area to be stripped. The slope falls away upstream and downstream. A break in slope occurs at about 900 feet elevation. Creep was noted to be negligible and talus minor. Stripping on this abutment would involve the removal of about two feet of soil and loose weathered rock plus approximately seven feet of weathered and jointed rock.

The left abutment has an average slope of about 70 per cent, falling away upstream and downstream. Some loose boulders are present and this abutment appears to be more deeply weathered than the right abutment. Minor creep was noted. Stripping on this abutment would include removal of about three feet of soil and loose weathered rock plus approximately seven feet of weathered rock.

The channel width is approximately 30 feet, with bedrock outcrops occupying about 15 per cent of the channel area. Alluvium therein is composed of silt, sand, pebbles, cobbles, and boulders. Stripping would require removal of about six feet of alluvium and loose weathered rock plus shaping of about three feet of bedrock.

An auxiliary dam would be required in a saddle which is located about 1,000 feet southeast of the left abutment. Stripping of about five feet of soil and loose weathered rock would be necessary there.

Earthfill materials are not available near the site in adequate quantities. Only about 24,000 cubic yards of impervious fill material were found to be available in the reservoir area. There are about 182,000 cubic yards of impervious fill material available in Rainbow Valley which is located about one and one-half miles north of the dam site and another 71,000 cubic yards in a small valley located about one mile southwest of Rainbow Valley. Pervious material in adequate quantity could be obtained from the San Luis Rey River channel at a haul distance of about eight miles. In order to reduce the amount of material hauled from borrow areas, it was assumed that about 28,900 cubic yards of pervious material could be salvaged from the foundation excavation and 19,600 cubic yards from the spillway cut. Rock for riprap or for a rockfill dam could be quarried from the sides of the reservoir.

For purposes of cost estimating a zoned earthfill dam was selected with a height of 178 feet above stream bed and creating a reservoir with a storage capacity of 10,000 acre-feet. The dam would have a crest elevation of 948 feet and side slopes of 3:1 upstream and downstream, requiring an embankment quantity of 1,530,000 cubic yards. The crest width would be 30 feet, consisting of a ten-foot width of impervious core section and ten-foot widths for each of the pervious sections. The impervious core section would have side slopes of 0.5:1 both upstream and downstream and would extend to bedrock, and the remainder of the embankment would be made up of upstream and downstream pervious sections, constructed of materials considered to be relatively free-draining. Moderate to heavy grouting would be necessary. Riprap, with a thickness of three feet normal to the upstream face of the dam, would be necessary to protect the face against wave action.

The spillway would be a concrete-lined chute with ogee weir control section placed in a cut through the ridge forming the left abutment. Maximum depth of cut would be about 35 feet with about five feet being overburden and

the remainder rock. The spillway would have a discharge capacity of about 3,400 second-feet, the estimated discharge of a once in a thousand year flood. Because of the preliminary nature of this design, no consideration was given to the effect of surcharge storage in the reservoir in reducing estimated peak flows over the spillway. Depth of water above the spillway during maximum flood discharge would be approximately five feet and the crest of the dam was assumed to be five feet above the maximum water surface elevation determined thereby.

Releases from the reservoir would be effected through a submerged inlet-outlet tower and controlled at a gate chamber under the main dam structure. The inlet-outlet conduit would be a 36-inch diameter steel pipe, encased in reinforced concrete from the tower to the gate chamber at the axis of the dam, and in an access conduit from the gate chamber to the valve house at the toe of the dam. A 36-inch butterfly valve would be placed in the line at the gate chamber and a 24-inch cone valve would be placed in the line at the valve house. The outlet conduit would be located along the right abutment.

It was estimated that time of construction would be one year, and stream flow during construction could be diverted through the outlet conduit.

There are only a few improvements in the reservoir area which may effect the purchase price of the lands therein, and no appreciable road relocation work is anticipated. Since impervious borrow material would be obtained from cultivated areas in Rainbow Valley, it was assumed for purposes of this estimate that the borrow areas therein would be purchased in fee. The major part of the pervious material would be imported from the San Luis Rey River Valley and would be taken from land which has no apparent value for cultivation purposes.

It should be noted that a rockfill dam could be constructed at this site with material quarried from the reservoir area. Only earthfill for the impervious core or aggregate for a concrete face slab would need to be imported. A detailed estimate of cost for an earthfill dam and reservoir at the Vallecitos site is presented in Table E-6.

TABLE E-6

ESTIMATED COST OF VALLECITOS DAM AND RESERVOIR
WITH STORAGE CAPACITY OF 10,000 ACRE-FEET

(Based on prices prevailing in 1956)

Elevation of crest of dam: 948 feet, U.S.G.S. datum	Capacity of reservoir to crest of spillway: 10,000 acre-feet
Elevation of crest of spillway: 938 feet	Capacity of spillway with 5-foot freeboard: 3,400 second-feet
Height of dam to spillway crest, above stream bed: 168 feet	

Item	Unit	Quantity	Unit price	Cost
CAPITAL COSTS				
Dam				
Exploration			lump sum \$	17,500
Diversion of stream and dewatering of foundation			lump sum	2,500
Stripping topsoil	cu.yd.	25,700	\$ 0.40	10,300
Excavation for embankment				
Foundation	cu.yd.	36,200	1.10	39,800
From borrow pits	cu.yd.	277,000	0.55	152,300
From stream bed	cu.yd.	1,337,500	1.20	1,605,000
Embankment				
Impervious	cu.yd.	241,600	0.16	38,700
Pervious	cu.yd.	1,264,400	0.14	177,000
Pervious, salvage	cu.yd.	48,500	0.20	9,700
Riprap	cu.yd.	39,100	3.50	136,900
Drilling grout holes	lin.ft.	20,300	3.00	60,900
Pressure grouting	cu.ft.	13,500	4.00	54,000
				<u>\$2,304,600</u>
Auxiliary Dam				
Stripping	cu.yd.	1,100	0.50	600
Embankment				
Impervious	cu.yd.	15,000	0.70	10,500
Pervious	cu.yd.	32,300	1.35	43,600
Riprap	cu.yd.	4,120	3.50	14,400
				<u>69,100</u>
Spillway				
Excavation, unclassified	cu.yd.	24,500	2.10	51,500
Concrete				
Weir and cutoff	cu.yd.	150	40.00	6,000
Floor	cu.yd.	310	35.00	10,800
Walls	cu.yd.	50	45.00	2,200
Reinforcing steel	lbs.	40,600	0.15	6,100
				<u>76,600</u>
Outlet Works				
Excavation				
Structures	cu.yd.	150	2.00	300
Conduit	cu.yd.	5,900	2.50	14,700
Backfill	cu.yd.	1,200	3.00	3,600

ESTIMATED COST OF VALLECITOS DAM AND RESERVOIR
WITH STORAGE CAPACITY OF 10,000 ACRE-FEET
(continued)

Item	Unit	Quantity	Unit price	Cost
CAPITAL COSTS				
Outlet Works (continued)				
Concrete				
Conduit and collars	cu.yd.	1,300	\$50.00	\$ 65,000
Structures	cu.yd.	300	75.00	22,500
Reinforcing steel	lbs.	102,000	0.15	15,300
Miscellaneous metalwork	lbs.	9,200	0.65	6,000
Steel pipe, 36-inch dia.	lbs.	72,300	0.30	21,700
Cone valve, 24-inch dia.			lump sum	12,000
Butterfly valve, 36-inch dia.			lump sum	<u>5,500</u>
				\$ 166,600
Reservoir				
Land and improvements			lump sum	408,300
Clearing reservoir lands	ac.	200	50.00	10,000
Road relocation	mi.	0.63	26,000	<u>16,400</u>
				<u>434,700</u>
Subtotal				\$3,051,600
Administration and engineering, 10%				\$ 305,100
Contingencies, 15%				457,700
Interest during construction				<u>76,300</u>
TOTAL				\$3,890,700

San Marcos Dam and Reservoir

The San Marcos dam site is located on San Marcos Creek in the SE $\frac{1}{4}$ of Sec. 30, T. 12 S., R. 3 W., S.B.B. & M. Stream bed elevation is about 310 feet, U.S.G.S. datum. Reservoir areas and storage capacities were obtained from United States Geological Survey quadrangles at a scale of 1:24,000 with a contour interval of 20 feet and are shown in Table E-7.

TABLE E-7

AREAS AND CAPACITIES OF SAN MARCOS RESERVOIR

Depth of water at dam, in feet	:	Water surface elevation U.S.G.S. datum in feet	:	Water surface area, in acres	:	Storage capacity in acre-feet
0		310		0		0
10		320		1		5
20		330		15		85
30		340		33		320
40		350		60		790
50		360		98		1,580
60		370		140		2,770
70		380		190		4,420
80		390		230		6,520
90		400		280		9,070
100		410		330		12,100
110		420		370		15,600
111		421		375		16,000
120		430		420		19,600
130		440		470		24,000
140		450		515		28,900

A preliminary geological reconnaissance of the dam site was made by this Department. The site is located at the entrance of a rather narrow canyon with steep slopes. Consideration of the topographic conditions and available material indicates that a combination earth and rockfill type of dam is best suited to the site.

The bedrock at this locality consists of a greenish grey, very hard, fine to medium grained granitic rock which contains inclusions of a darker medium

grained rock which could possibly be gabbro. Joints were noted which extend to an unknown depth. No faults or slides were noted, nor were shears apparent. The general appearance of the area indicates that it is only moderately active seismically.

The right abutment has an even slope of 65 per cent, falling away sharply in the upstream and downstream directions. Outcrops occupy 5 per cent of the surface area. There are no breaks in slope and creep is negligible. It is estimated that about five feet of soil and loose weathered rock plus eight feet of jointed blocky rock would have to be stripped from this abutment.

The left abutment has an average slope of about 65 per cent. The bedrock is jointed and not as much exposed as on the right abutment. The soil and weathered rock is about five feet in depth and the bedrock is jointed and blocky for a depth of about ten feet. Stripping would be necessary to an average depth of about 13 feet.

The channel section is about 40 feet wide with outcrops occupying 75 per cent of the surface area. Bedrock is very near the surface in the channel section. Channel alluvium consists of sand, cobbles and boulders to a depth of about two feet in several small pockets. It is estimated that the channel section would require stripping to a maximum depth of about seven feet.

Adequate quantities of earth and rockfill materials are available near the site. About 985,000 cubic yards of material suitable for use in the impervious section of the dam were found in the reservoir area about one-half mile to the northeast of the dam site. Additional impervious fill material may be obtained from San Marcos Valley which is located about two and one-half miles to the northeast of the site by road. About 159,000 cubic yards of material for the rock section could be salvaged from the spillway excavation. 520,000 cubic yards of possibly pervious material is to be found in the reservoir area, approximately three-fourths of a mile east of the dam site.

For cost estimating purposes, a zoned earth and rockfill type dam with a height of 135 feet above stream bed was considered which would create a reservoir storage capacity of 16,000 acre-feet. The dam would have a crest elevation of 445 feet and upstream and downstream side slopes of 2.5:1. The crest width would be 30 feet, comprised of a 10-foot width for the impervious core section and 10-foot widths for each of the rockfill sections. The impervious core would have side slopes of 0.75 to 1 upstream and downstream and would extend to bedrock and the remainder of the dam embankment would be made up of upstream and downstream pervious sections constructed of pervious material. Because there was doubt that the proposed pervious material would be free-draining, the slopes of the dam were assumed to be flatter than ordinarily required for a structure of this height. Pervious filter material would be placed between the impervious core and the pervious fill because of expected large sizes of rock in the latter material. Total fill would be 442,000 cubic yards, and grading of the rock on the upstream face of the dam would be comparable to riprap to protect against wave action. Grouting along the axis of the dam was assumed to be moderate in amount as the open joints seem to tighten considerably with depth.

The spillway would be a concrete-lined chute with ogee weir control section placed in a cut around the end of the dam on the left abutment. The maximum depth of cut would be about 120 feet consisting of about five feet of soil and weathered rock and the remainder in granodiorite. The spillway would have a discharge capacity of 30,600 second-feet, the estimated peak flow of a once in a thousand year flood. Because of the preliminary nature of this design, no consideration was given to the effect of surcharge storage in the reservoir on reducing the estimated peak flows over the spillway. Depth of water above the spillway during maximum flood discharge would be approximately 19 feet and the crest of the dam was assumed to be five feet above the maximum water surface elevation determined thereby.

Releases from the reservoir would be effected through a submerged outlet tower equipped with a trash rack and controlled at a gate chamber under the main dam structure at the proposed axis. The outlet conduit would be located on bedrock along the right abutment. It would consist of a 36-inch diameter steel pipe encased in concrete from the tower to the gate chamber and a 36-inch diameter steel pipe placed in an access conduit extending from the gate chamber to the valve house at the downstream toe of the dam. Releases would be regulated by a 30-inch butterfly valve in the line located in the gate chamber, and a 24-inch cone valve placed in the line at the valve house.

Estimated time of construction is one year and stream diversion would be effected through the outlet conduit. Construction of about 4.4 miles of relocated county road would be required.

A detailed cost estimate of San Marcos Dam and Reservoir is presented in Table E-8. It will be noted in the table that the cost of spillway excavation constitutes a substantial portion of the total cost. This cost could be reduced if the effect of surcharge storage on reducing the flood flow is taken into account. Also, it may be more economical to build a higher dam which could utilize a saddle spillway location behind the left abutment. The greater reservoir capacity created by a higher dam could be utilized to conserve natural runoff or as a substitute for storage at some other location along the proposed San Diego Aqueduct.

TABLE E-8

ESTIMATED COST OF SAN MARCOS DAM AND RESERVOIR
WITH STORAGE CAPACITY OF 16,000 ACRE-FEET

(Based on prices prevailing in 1956)

Elevation of crest of dam: 445 feet, U.S.G.S. datum	Capacity of reservoir to crest of spillway: 16,000 acre-feet
Elevation of crest of spillway: 421 feet	Capacity of spillway with 5-foot freeboard: 30,600 second-feet
Height of dam to spillway crest, above stream bed: 111 feet	

	:	Unit	:	Quantity	:	Unit	:	price	:	Cost
CAPITAL COSTS										
Dem										
Exploration						lump sum	\$			15,000
Diversion of stream and dewatering of foundation						lump sum				5,000
Stripping topsoil	cu.yd.			15,300		\$ 0.50				7,700
Excavation for embankment										
Foundation	cu.yd.			31,500		1.10				34,700
From borrow pits	cu.yd.			187,200		0.38				71,100
From stream bed	cu.yd.			132,800		0.45				59,800
Embankment										
Impervious	cu.yd.			162,800		0.16				26,000
Pervious	cu.yd.			120,700		0.14				16,900
Rock, salvage	cu.yd.			159,000		0.20				31,800
Drilling grout holes	lin.ft.			5,880		3.00				17,600
Pressure grouting	cu.ft.			3,920		4.00				15,700
									\$	301,300
Spillway										
Excavation, unclassified	cu.yd.			198,800		2.50				497,000
Concrete										
Weir and cutoff	cu.yd.			322		40.00				12,900
Floor	cu.yd.			630		35.00				22,000
Walls	cu.yd.			195		45.00				8,800
Reinforcing steel	lbs.			90,400		0.15				13,600
										554,300
Outlet Works										
Excavation										
Structures	cu.yd.			500		2.00				1,000
Conduit	cu.yd.			4,100		2.50				10,300
Backfill	cu.yd.			900		3.00				2,700
Concrete										
Conduit and collars	cu.yd.			980		50.00				49,000
Structures	cu.yd.			420		75.00				31,500
Reinforcing steel	lbs.			126,000		0.15				18,900
Miscellaneous metalwork	lbs.			7,600		0.65				4,900
Steel pipe, 36-inch dia.	lbs.			57,000		0.30				17,100
Cone valve, 24-inch dia.						lump sum				12,000
Butterfly valve, 30-inch dia.						lump sum				5,000
										152,400

ESTIMATED COST OF SAN MARCOS DAM AND RESERVOIR
WITH STORAGE CAPACITY OF 16,000 ACRE-FEET
(continued)

Item	Unit	Quantity	Unit price	Cost
CAPITAL COSTS				
Reservoir				
Land and improvements			lump sum	\$ 365,500
Clearing reservoir lands	ac.	500	\$ 50.00	25,000
Road relocation	mi.	4.4	20,000	88,000
Access road			lump sum	<u>10,000</u>
				\$ 488,500
Subtotal				\$1,496,500
Administration and engineering, 10%				\$ 149,600
Contingencies, 15%				224,500
Interest during construction				<u>37,400</u>
TOTAL				\$1,908,000

Woodson Dam and Reservoir

The Woodson dam site is in the NW $\frac{1}{4}$ of Sec. 29, T. 13 S., R. 1 W., S.B.B. & M. Stream bed elevation is about 650 feet, U.S.G.S. datum. Reservoir areas and storage capacities for various stages of water surface elevation were obtained from United States Geological Survey quadrangles at a scale of 1:24,000, with a contour interval of 20 feet, and are shown in Table E-9.

TABLE E-9

AREAS AND CAPACITIES OF WOODSON RESERVOIR

Depth of water at dam, in feet	: Water surface elevation U.S.G.S. datum in feet	: Water surface area, in acres	: Storage capacity in acre-feet
0	650	0	0
10	660	1	5
20	670	10	60
30	680	19	200
40	690	33	460
50	700	47	860
60	710	61	1,400
70	720	75	2,080
80	730	88	2,900
90	740	100	3,840
100	750	110	4,890
110	760	125	6,060
120	770	130	7,340
125	775	140	8,010
130	780	145	8,730
140	790	160	10,200
150	800	170	11,900

The site is located at a prominent constriction formed by a ridge in a rather small valley. Based upon a preliminary geological reconnaissance this site is considered suitable for either an earthfill or masonry type of dam.

Bedrock of the area is a massive, grey-white, granodiorite of the Cretaceous age. It is hard, medium grained in character, and fairly resistant to weathering. The bedrock at the dam site is slightly blocky, exhibiting widely spaced rectangular jointing. There are no apparent faults or shears and

no slides. The seismicity of the area is moderate to low, the Elsinore fault zone being approximately 20 miles to the northeast.

The right abutment has an even 65 per cent slope falling away upstream and downstream. Bedrock outcrops are prominent, making up approximately 40 per cent of the surface area. There are no breaks in slope, talus is minor and creep negligible. Large loose blocks on the outcrops would need to be cleared when stripping the abutment. For an earthfill structure, an average of about two feet of soil and loose weathered rock plus about five feet of weathered rock would be stripped on this abutment.

The left abutment has an even slope of about 75 per cent falling away sharply upstream and downstream. Bedrock outcrops make up about 60 per cent of the surface area, exhibiting a slightly less weathered character than that of the right abutment. Loose blocks up to ten feet in diameter would have to be cleared from the surface when stripping. There are no breaks in slope, creep is negligible and talus is minor. An average thickness of about one foot of soil and loose weathered rock plus about five feet of weathered rock would be sufficient stripping on this abutment for an earthfill dam.

Channel width is approximately 100 feet, with a few bedrock outcrops. Alluvial fill covering the channel to an estimated average depth of eight feet consists of silt, sand, and some gravel and scattered boulders. Stripping in the channel would include about eight feet of alluvium plus about three feet of weathered rock.

Only limited amounts of earthfill materials were found to be available near the site. About 170,000 cubic yards each of impervious and random fill material are contained in the stream channel extending for a distance of about one mile upstream from the dam site. Residuum lying on the hillside above Green Valley, approximately one mile west of the site, would provide about 230,000 cubic yards of impervious fill material, and additional impervious fill

could be obtained along the Poway-Green Valley road approximately 1.5 miles southwest of the dam site. Adequate quantities of random fill material may be obtained from the Poway formation which outcrops approximately five miles west of the site. In addition, about 37,100 cubic yards of foundation excavation and 11,100 cubic yards of spillway excavation could be salvaged for use in the random fill sections. Rock for riprap could be obtained from material excavated in the spillway cut.

The dam would be of the zoned earthfill type with a height of 140 feet above stream bed, creating a reservoir storage capacity of 8,000 acre-feet. Both upstream and downstream slopes would be 2.5:1 and the impervious section would have slopes of 1:1. The dam would have a crest elevation of 790 feet and would contain about 705,000 cubic yards of fill. The crest width of the dam would be 30 feet, consisting of a ten-foot width for the impervious core and ten-foot widths for each of the upstream and downstream random fill sections. The impervious core was assumed to extend to bedrock where light grouting would be required.

Because the random fill material in the upstream and downstream sections is not considered to be free-draining, gravel drains would be provided at the downstream face of the impervious core to remove any leakage occurring through the impervious section and at the abutment contacts. A gravel blanket with a thickness of six feet normal to the downstream face of the impervious section would be placed at the contact between the impervious and random fill and would extend to a height of two-thirds of the distance between the stream bed and the spillway lip. Intercepted seepage would be carried away from the base of the blanket to the downstream toe of the dam by gravel drains. The upstream face of the random fill section would be protected from wave action by riprap placed to a depth of three feet normal to the slope.

The spillway would consist of an ogee weir control section and a concrete-lined apron placed in a cut through a saddle behind the left abutment. The maximum depth of cut in the saddle would be 25 feet consisting of about five feet of residuum and weathered rock and about 20 feet of granodiorite. The spillway would have a discharge capacity of 9,400 second-feet, which is the estimated peak flow of a once in a thousand year flood. Because of the preliminary nature of this design, no consideration was given to the effect of surcharge storage in the reservoir in reducing the estimated peak flows over the spillway. Depth of water above the spillway lip during maximum flood discharge would be approximately ten feet and the crest elevation of the dam was assumed to be five feet above the maximum water surface elevation so defined.

Releases from the reservoir would be effected through a submerged inlet-outlet tower. The inlet-outlet conduit would consist of a 30-inch diameter steel pipe encased in reinforced concrete from the tower to a gate chamber under the dam structure at the proposed axis, and a 30-inch diameter steel pipe placed in an access conduit extending from the gate chamber to the valve house at the toe of the dam. Releases would be regulated by a 30-inch butterfly valve placed in the line at the gate chamber and a 24-inch cone valve placed in the line at the valve house.

Estimated time of construction is one year, and stream flow could be diverted through the outlet conduit during construction.

Included in the cost of lands and improvements is the cost of acquisition of land from which borrow material would be obtained and which lies outside the reservoir area.

A detailed cost estimate for Woodson Dam and Reservoir is presented in Table E-10.

TABLE E-10

ESTIMATED COST OF WOODSON DAM AND RESERVOIR
WITH STORAGE CAPACITY OF 8,000 ACRE-FEET

(Based on prices prevailing in 1956)

Elevation of crest of dam: 790 feet, U.S.G.S. datum	Capacity of reservoir to crest of spillway: 8,000 acre-feet
Elevation of crest of spillway: 775 feet	Capacity of spillway with 5-foot freeboard: 9,400 second-feet
Height of dam to spillway crest, above stream bed: 125 feet	

Item	Unit	Quantity	Unit price	Cost
CAPITAL COSTS				
Dam				
Exploration			lump sum \$	15,000
Diversion of stream and dewatering of foundation			lump sum	5,000
Stripping topsoil	cu.yd.	8,060	\$ 0.50	4,000
Excavation for embankment				
Foundation	cu.yd.	41,030	1.25	51,600
From borrow pits	cu.yd.	393,200	0.60	235,900
From quarry	cu.yd.	320,400	0.40	128,200
Embankment				
Impervious	cu.yd.	278,600	0.16	44,600
Random	cu.yd.	341,900	0.14	47,900
Random, salvage	cu.yd.	48,200	0.20	9,600
Rock riprap	cu.yd.	17,200	3.50	60,200
Drilling grout holes	lin.ft.	8,640	3.00	25,900
Pressure grouting	cu.ft.	5,760	4.00	23,000
Gravel drains	cu.yd.	19,370	3.50	67,800
				\$ 718,700
Spillway				
Excavation, unclassified	cu.yd.	33,300	2.40	79,900
Concrete				
Weir and cutoff	cu.yd.	190	40.00	7,600
Floor	cu.yd.	300	35.00	10,500
Walls	cu.yd.	60	45.00	2,700
Reinforcing steel	lbs.	41,800	0.15	6,300
				107,000
Outlet Works				
Excavation				
Structures	cu.yd.	100	2.00	200
Conduit	cu.yd.	3,880	2.50	9,700
Backfill	cu.yd.	1,140	3.00	3,400
Concrete				
Conduit and collars	cu.yd.	1,010	50.00	50,500
Structures	cu.yd.	250	75.00	18,800
Reinforcing steel	lbs.	88,800	0.15	13,300
Miscellaneous metalwork	lbs.	6,000	0.65	3,900
Steel pipe, 30-inch dia.	lbs.	48,800	0.30	14,600

ESTIMATED COST OF WOODSON DAM AND RESERVOIR
WITH STORAGE CAPACITY OF 8,000 ACRE-FEET
(continued)

Item	: Unit	: Quantity	: Unit price	: Cost
CAPITAL COSTS				
Outlet Works (continued)				
Cone valve, 24-inch dia.			lump sum \$	12,000
Butterfly valve, 30-inch dia.			lump sum	<u>5,000</u> \$ 131,400
Reservoir				
Land and improvements			lump sum	435,600
Clearing reservoir lands ac.		170	\$75.00	12,800
Road relocation mi.		2.1	25,000	<u>52,500</u> <u>500,900</u>
Subtotal				\$1,458,000
Administration and engineering, 10%				\$ 145,800
Contingencies, 15%				218,700
Interest during construction				<u>36,500</u>
TOTAL				\$1,859,000

Carroll Dam and Reservoir

The Carroll dam site is located on a tributary to Carroll Canyon in the NE 1/4 of Sec. 32, T. 14 S., R. 2 W., S.B.D.&M. Stream bed elevation at the site is about 575 feet. Reservoir areas and storage capacities for various water surface elevations were obtained from United States Geological Survey quadrangles at a scale of 1:24,000, with a contour interval of 20 feet, and are shown in Table E-11.

TABLE E-11

AREAS AND CAPACITIES OF CARROLL RESERVOIR

Depth of water at dam, in feet	: Water surface elevation U.S.G.S. datum in feet	: Water surface area, in acres	: Storage capacity in acre-feet
0	575	0	0
5	580	2	5
15	590	7	50
25	600	11	140
35	610	16	280
45	620	22	460
55	630	28	720
65	640	38	1,040
75	650	50	1,480
85	660	64	2,060
95	670	79	2,770
105	680	96	3,640
115	690	120	4,700
125	700	140	6,000
135	710	165	7,530
139	714	180	8,220
145	720	190	9,300
150	725	210	10,300

Topography of the dam site and reservoir area is low in relief. Intermittent streams have developed irregular ridges and gullies. Preliminary geological reconnaissance by this Department in 1956 indicated that an earth-fill dam structure is the most suitable for this site, considering topographic and foundation conditions and availability of construction materials.

Bedrock in the area is overlain by a thick section of conglomerate, identified as the Poway conglomerate of the Eocene age. Bedrock outcrops observed consisted of volcanics tentatively identified as the Santiago Peak formation. The abutments and channel section of the dam site are meta-volcanic bedrock. The rock is very hard, aphanitic, blue black in color, and moderately blocky to very blocky. Locally, the rock exhibits foliation and some recemented breccia. No faults are apparent, but shears are prominent in the spillway cut of a small dam existing upstream from the proposed dam axis. Moderate to closely spaced jointing is evident but it appears to close with depth. The reservoir area is in the conglomerate formation, which is moderately weathered, buff to red brown in color, and slightly cemented.

The right abutment has an even slope of about 50 per cent, falling away upstream and downstream. Outcrops occupy 10 per cent of the surface area. No landslides or talus were noted and creep is negligible. Required stripping on this abutment would include about two feet of soil and loose weathered rock plus about six feet of weathered rock.

The left abutment has an even slope of 55 per cent falling away upstream. There are no breaks in slope and outcrops occupy 15 per cent of the surface area. Creep is negligible and no landslides or talus were noted. It is estimated that about two feet of soil and loose weathered rock and about eight feet of weathered rock would be stripped from this abutment.

The channel width is 30 feet and bedrock outcrops occupy about 10 per cent of that width. Unconsolidated material in the channel consists of boulders, cobbles, and sand, to an approximate depth of two feet. Stripping for an earthfill structure would require removal of an average of two feet of channel fill plus four feet of weathered rock. It should be noted that there is a small rockfill dam with a concrete diaphragm located at the upstream edge of the presently considered construction site, which structure could be incorporated into the proposed structure. Moderate grouting of the dam foundation would be required.

Suitable impervious material is not available in the reservoir area. However, approximately 241,000 cubic yards of impervious material occurs northwest of the site in Los Penasquitos Canyon and in a tributary stream at a maximum distance of about 3.0 miles. Pervious material in adequate supply could be obtained from the conglomerate in the reservoir area. This material is not considered to be free-draining and is therefore classified as random fill. Approximately 80,200 cubic yards of pervious material could be salvaged from the foundation and spillway excavations.

The proposed dam would have a height of 150 feet above stream bed and would create a reservoir with a storage capacity of 8,000 acre-feet. The dam would have a crest elevation of 725 feet, and side slopes of 2.5:1 upstream and downstream. The crest width would be 30 feet, consisting of a 10-foot width for the crest of the impervious core and 10-foot widths for the crests of each of the upstream and downstream random fill sections. The impervious core section would have side slopes of 1:1 for its upstream and downstream faces and would extend to bedrock. Upstream and downstream random fill sections would make up the remainder of the embankment. The upstream face of the dam would be protected against wave action by rock riprap to a depth of three feet normal to the upstream face.

A low dike about 1,700 feet in length would be required along the ridge forming the left abutment. This would be an earthfill structure similar to the main dam. The total fill in both embankments would be about 954,000 cubic yards.

The spillway would be a concrete-lined chute with ogee weir control section placed in a cut located around the end of the dam on the right abutment. The maximum depth of cut would be about 20 feet with about 10 feet being in overburden and 10 feet in conglomerate underlain by volcanic rock. The spillway would have a discharge capacity of 1,200 second-feet, the estimated peak

flow of once in a thousand year flood. For this estimate, the effect of surcharge storage on the reservoir area was not considered in determination of the required discharge capacity of the spillway structure. During maximum discharge, the depth of water above the spillway would be about six feet and the crest of the dam was assumed to be five feet above the maximum water surface elevation so defined.

Releases from the reservoir would be effected through a submerged outlet tower equipped with a trash rack structure, and controlled at a gate chamber located under the main dam structure at the axis of the dam. The inlet-outlet conduit would be a 36-inch diameter steel pipe encased in reinforced concrete from the tower to the gate chamber and a 36-inch steel pipe placed in an access conduit extending from the gate chamber to a valve house at the toe of the dam. Releases would be regulated by a 36-inch butterfly valve located in the gate chamber and a 24-inch cone valve located in the valve house.

Time of construction is estimated to be one year, and during construction stream flow would be passed through the outlet conduit. There are no roads or utilities within the area of the proposed reservoir. The cost of land outside of the reservoir area from which borrow material would be obtained is included in the estimate of costs of reservoir lands and improvements hereinafter presented.

A detailed estimate of the cost of Carroll Dam and Reservoir is presented in Table E-12.

TABLE E-12

ESTIMATED COST OF CARROLL DAM AND RESERVOIR
WITH STORAGE CAPACITY OF 8,000 ACRE-FEET

(Based on prices prevailing in 1956)

Elevation of crest of dam: 725 feet, U.S.G.S. datum	Capacity of reservoir to crest of spillway: 8,000 acre-feet
Elevation of crest of spillway: 714 feet	Capacity of spillway with 5-foot
Height of dam to spillway crest, above stream bed: 139 feet	freeboard: 1,200 second-feet

Item	Unit	Quantity	Unit price	Cost
CAPITAL COSTS				
Dam				
Exploration			lump sum \$	20,000
Diversion of stream and dewatering of foundation			lump sum	5,000
Stripping topsoil	cu.yd.	34,600	\$ 0.50	17,300
Excavation for embankment				
Foundation	cu.yd.	90,600	0.90	81,500
From borrow pits	cu.yd.	447,700	0.55	246,200
From quarry	cu.yd.	520,700	0.60	312,400
Embankment				
Impervious	cu.yd.	389,300	0.16	62,300
Pervious	cu.yd.	452,800	0.14	63,400
Pervious, salvage	cu.yd.	81,200	0.25	20,300
Riprap	cu.yd.	30,900	3.00	92,700
Drilling grout holes	lin.ft.	3,720	3.00	11,200
Pressure grouting	cu.ft.	24,800	4.00	99,200
				<u>\$1,031,500</u>
Spillway				
Excavation, unclassified	cu.yd.	10,500	1.70	17,900
Concrete				
Weir and cutoff	cu.yd.	40	40.00	1,600
Floor	cu.yd.	100	35.00	3,500
Walls	cu.yd.	30	45.00	1,400
Reinforcing steel	lbs.	12,200	0.15	1,800
				<u>26,200</u>
Outlet Works				
Excavation				
Structures	cu.yd.	150	2.00	300
Conduit	cu.yd.	4,100	0.90	3,700
Backfill	cu.yd.	950	3.00	2,900
Concrete				
Conduit and collars	cu.yd.	1,090	50.00	54,500
Structures	cu.yd.	300	75.00	22,500
Reinforcing steel	lbs.	106,500	0.15	16,000
Miscellaneous metalwork	lbs.	9,000	0.65	5,900
Steel pipe, 36-inch dia.	lbs.	58,500	0.30	17,600
Cone valve, 24-inch dia.			lump sum	12,000
Butterfly valve, 36-inch dia.			lump sum	<u>5,500</u>
				140,900

ESTIMATED COST OF CARROLL DAM AND RESERVOIR
WITH STORAGE CAPACITY OF 8,000 ACRE-FEET
(continued)

Item	: Unit	: Quantity	: Unit price	: Cost
CAPITAL COSTS				
Reservoir				
Land and improvements			lump sum \$	163,200
Clearing reservoir lands ac.		210	\$40.00	8,400
Access road			lump sum	<u>10,000</u>
				\$ 181,600
Subtotal				\$1,380,200
Administration and engineering, 10%				\$ 138,000
Contingencies, 15%				207,000
Interest during construction				<u>34,500</u>
TOTAL				\$1,759,700

Enlargement of San Vicente Reservoir

The existing San Vicente Dam is a straight concrete gravity structure with central overpour spillway ending in a concrete bucket section. It is 190 feet in height from stream bed to spillway crest, has a crest length of 980 feet, and creates a reservoir with a storage capacity of 90,230 acre-feet. Elevation of the spillway lip of the dam is 650 feet. The outlet works consist of a semi-circular tower attached to the upstream face of the dam. At 30-foot increments of elevation saucer valves are provided which are operated from a control platform at the top of the tower. Three 36-inch diameter cast-iron outlet pipes discharge through the dam from the base of the tower. Two of the outlet pipes are provided with valves at a valve house at the downstream toe of the dam, and the third is covered by a blind flange.

Water surface areas and reservoir storage capacities for various stages of water surface elevation were obtained from a table supplied by the City of San Diego dated August 27, 1943, and are shown in Table E-13 for the portion of the reservoir above the spillway lip elevation of the existing dam.

TABLE E-13

AREAS AND CAPACITIES OF ENLARGED SAN VICENTE RESERVOIR

Increase in depth of water at dam, in feet	: : U.S.G.S. datum : in feet	Water surface elevation in feet	: : Water surface : area, in acres :	: : Storage capacity : in acre-feet :
0		650	1,070	90,200
5		655	1,090	95,600
10		660	1,110	101,100
15		665	1,140	106,800
20		670	1,160	112,500
21		671	1,170	113,700
25		675	1,190	118,400
30		680	1,210	124,400
35		685	1,230	130,500

Bedrock at the San Vicente Dam is composed of moderately jointed granitic and metamorphic rock which is hard and durable when fresh. No evidence of faulting was observed at the dam or in the nearby vicinity. The area is considered to be moderately active seismically as the Elsinore fault zone lies 24 miles to the northeast. The pointing of the foundation material is moderately strong with generally clean joints.

Many loose boulders are present and the depth of weathering varies with rock type. Stripping estimates for the right abutment would necessitate removal of about five feet of weathered rock and about five feet of jointed bedrock. The channel section downstream from the existing structure would require removal of about 12 feet of alluvial fill. Stripping on the left abutment would consist of the removal of about eight feet of weathered rock and about five feet of jointed metamorphic rock.

The existing dam was constructed with the consideration in mind of raising it at some future date, by adding concrete on the downstream side. Although grouting work done during the original construction work was based upon requirements for a higher dam, additional grouting may be required for the raising operations herein considered. No stepping or other special treatment was given to the downstream face of the existing dam to facilitate keying in the new concrete work. Studies indicate that special methods of construction will be required to properly place the new concrete on the old surface with due allowance and consideration for shrinkage due to cooling and settling. A further problem presented is that of securing a good seal along the upstream contact between the old structure and the new section. The surface between the new and old concrete must be thoroughly drained, and galleries provided to permit inspection of such drainage. In order to increase the storage capacity of the reservoir about 23,000 acre-feet, the crest of the spillway would be raised

21 feet above its present elevation to an elevation of 671 feet. Height of the enlarged dam would be 211 feet from stream bed to spillway crest.

For cost estimating purposes the plan of enlargement contemplates making the upstream face of the new work vertical, and providing a batter of 0.8:1 on the downstream face. The capacity and other features of the spillway would be similar to those now existing. The crest width of the raised dam would be 30 feet. The outlet tower would be raised by removing the existing operating platform and then extending the tower. The original design of the tower included allowance for this extension. A 36-inch diameter butterfly valve would be installed in the tower near the base of the new lift, and a 24-inch diameter cone valve would be placed in the outlet pipe which is presently plugged. No temporary outlet works would be necessary during the enlargement work, and it was assumed that there would be no appreciable interference with reservoir operation.

The City of San Diego now owns rights of way required for the enlargement, and no highway or utility relocation would be involved. A detailed estimate of cost of enlargement of San Vicente Dam is presented in Table E-14.

TABLE E-14

ESTIMATED COSTS OF ENLARGEMENT OF SAN VICENTE RESERVOIR
TO A STORAGE CAPACITY OF 113,000 ACRE-FEET

(Based on prices prevailing in 1956)

Elevation of crest of dam: 680 feet	Increase in capacity of reservoir: 23,000 acre-feet
U.S.G.S. datum	
Elevation of crest of spillway: 671 feet	Capacity of spillway with 0.5 foot
Increase in depth of water: 21 feet	freeboard: 26,000 second-feet

Item	Unit	Quantity	Unit price	Cost
CAPITAL COSTS				
Dam				
Exploration and grouting			lump sum	\$ 25,000
Existing concrete preparation	sq.yd.	16,000	\$ 4.00	64,000
Excavation	cu.yd.	36,000	3.00	108,000
Mass concrete	cu.yd.	167,000	17.50	2,922,500
Cooling concrete	cu.yd.	167,000	0.50	<u>83,500</u>
				\$3,203,000
Spillway and Parapet Walls				
Reinforced concrete	cu.yd.	490	45.00	22,000
Reinforcing steel	lbs.	36,000	0.15	<u>5,400</u>
				27,400
Outlet Works				
Control house construction			lump sum	15,000
Butterfly valve, 36-inch diameter	each	1	5,000	5,500
Cone valve, 24-inch dia.	each	1	12,000	12,000
Miscellaneous metalwork	lbs.	129,000	0.65	<u>83,800</u>
				116,300
Reservoir				
Clearing	ac.	100	50.00	<u>5,000</u>
Subtotal				\$3,351,700
Administration and engineering, 10%				\$ 335,200
Contingencies, 15%				502,800
Interest during construction				<u>83,800</u>
TOTAL				\$4,273,500

Enlargement of Lower Otay Reservoir

Lower Otay Reservoir is created by the existing Savage Dam on the Otay River which was constructed in 1919. The dam is a curved concrete gravity structure with a height of about 145 feet from stream bed to crest of dam and a crest length of about 750 feet. It has a central overpour spillway ending in a concrete bucket section and an auxiliary chute spillway located on the left abutment. Flash boards were installed on the spillways in 1923 to raise the maximum water surface to an elevation of 491 feet, and creating a storage capacity of about 56,300 acre-feet.

Water surface areas and reservoir storage capacities for enlargement of Lower Otay Reservoir were computed from United States Geological Survey quadrangles with a scale of 1:24,000 and a contour interval of 20 feet, and are shown in Table E-15. An increase in storage capacity of about 56,000 acre-feet could be accomplished by raising the normal water surface approximately 36 feet to an elevation of about 527 feet.

TABLE E-15

AREAS AND CAPACITIES OF ENLARGED LOWER OTAY RESERVOIR

Increase in depth of water at dam, in feet	: Water surface elevation U.S.G.S. datum in feet	: Water surface area, in acres	: Storage capacity in acre-feet
0	491	1,120	56,300
9	500	1,370	67,500
19	510	1,580	82,200
29	520	1,770	99,000
36	527	1,890	111,800
39	530	1,940	117,600
49	540	2,120	137,800

Bedrock at the Savage dam site consists of a grey-black meta-volcanic, presumed to be of the Santiago Peak group. It is a hard, fine to coarse grained,

massive to fractured, rock that develops blocky outcrops. The seismicity of the area is moderate to low. No faults were observed near the axis. However, small shears were noted. The additional grouting requirements for an enlarged structure should be moderate as the fractures appear to close with depth.

The right abutment slope is fairly uniform above the existing dam. Stripping for a concrete structure would include removal of about two feet of soil and about ten feet of weathered and fractured bedrock. In the channel section an estimated 15 feet of overburden would be removed under the base of the new concrete work to shape the bedrock and key in the new work with the old structure. The left abutment above the existing dam would require removal of about two feet of soil plus about 15 feet of fractured and weathered rock for the new concrete structure. To raise the existing structure, the axis on the left abutment would be realigned for best utilization of the conformation of the slope.

Although Savage Dam was not constructed with the consideration of raising it, the difficulties involved are not insurmountable. The special construction methods and precautions required would be similar to those necessary to raise San Vicente Dam. In addition, the soundness of the existing concrete structure and foundation should be ascertained prior to any enlargement. The additional concrete would be placed with the upstream face vertical and a batter of 0.8:1 on the downstream face. The crest width would be 30 feet.

The new spillway structures would have a discharging capacity of 65,000 second-feet which is the estimated peak flow of the once in one thousand year flood flow without allowance for the effect of surcharge storage on the reservoir surface. The new spillway structure would be a central overpour with a concrete bucket section and an auxiliary overpour spillway located on the left abutment. The spillways would be provided with five tainter gates, each 15 feet high and 40 feet wide; three of which would be installed in the central section

and two on the auxiliary section. These gates could be operated so as to pass the more frequent floods through the central spillway with only emergency use of the auxiliary spillway on the left abutment where spillway discharges could result in some erosional effects.

A new inlet tower would be constructed in the reservoir for the raised structure. The tower would have a height of about 150 feet and a diameter of 18 feet. Releases would be controlled by eight 48-inch diameter butterfly valves installed at selected elevations in the tower. Although a special connection would be required between the new tower and the existing outlet tunnel, it is believed that there is adequate capacity in the tunnel to accommodate the increased releases of water. Construction of the new outlet tower could only be accomplished with the existing reservoir at a very low stage. However, it would be possible to defer its construction until the proposed San Diego Aqueduct were completed to the vicinity of Otay Reservoir and provide water service through the aqueduct while construction operations were proceeding.

If the water surface of Lower Otay Reservoir were raised, there would be a possibility of leakage through the permeable San Diego formation which forms the upper portion of the west side of the reservoir closure. To prevent this a blanket of impervious material averaging six feet in thickness would be placed on approximately 250 acres of the formation subject to inundation. The clay blanket would be protected from wave action by a layer of gravel about 1.5 feet in thickness normal to the slope.

Two small auxiliary dams would be required in saddles along the westerly edge of the reservoir. They would each have a height of about 20 feet, crest lengths of about 400 feet, and contain approximately 15,000 cubic yards of fill.

Enlargement of Lower Otay Reservoir would require the relocation of about seven miles of county road along its northerly and westerly edges.

It is estimated that approximately 620 acres of additional rights of way would be purchased to accommodate the contemplated 36-foot rise in water surface elevation.

A detailed estimate of the cost of raising Savage Dam is presented in Table E-16.

TABLE E-16

ESTIMATED COSTS OF ENLARGEMENT OF LOWER OTAY RESERVOIR
TO A STORAGE CAPACITY OF 112,000 ACRE-FEET

(Based on prices prevailing in 1956)

Elevation of crest of dam: 532 feet, U.S.G.S. datum	Increase in capacity of reservoir: 56,000 acre-feet
Elevation of top of gates: 527 feet	Capacity of spillways with 2.5-foot
Increase in depth of water: 36 feet	freeboard: 65,000 second-feet

Item	Unit	Quantity	Unit price	Cost
CAPITAL COSTS				
Dam				
Exploration and grouting			lump sum	\$ 50,000
Existing concrete preparation	sq.yd.	7,600	\$ 4.00	30,400
Excavation	cu.yd.	37,000	3.00	111,000
Mass concrete	cu.yd.	149,000	17.50	2,607,500
Cooling concrete	cu.yd.	149,000	0.50	74,500
				<u>\$2,873,400</u>
Spillway				
Gates and hoists			lump sum	200,000
Reinforced concrete	cu.yd.	1,260	45.00	56,700
Reinforcing steel	lbs.	94,600	0.15	14,200
Bridge			lump sum	30,000
				<u>300,900</u>
Outlet Works				
Connection to outlet tunnel			lump sum	10,000
Concrete tower	cu.yd.	720	80.00	57,600
Concrete base	cu.yd.	660	30.00	19,800
Reinforcing steel	lbs.	125,600	0.15	18,800
Butterfly valve, 48-inch dia.	each	8	8,000	64,000
Miscellaneous metalwork	lbs.	112,000	0.65	72,800
				<u>243,000</u>
Reservoir				
Land and improvements			lump sum	124,000
Road relocation			lump sum	328,000
Auxiliary dam	each	2	15,000	30,000
Clay blanket			lump sum	1,815,000
				<u>2,297,000</u>
Subtotal				\$5,714,300
Administration and engineering, 10%				\$ 571,400
Contingencies, 15%				857,100
Interest during construction				<u>142,800</u>
TOTAL				<u>\$7,285,600</u>

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